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Alberta
ENVIRONMENT

Technical Manual

Procedures and Methods for Evaluating Water Quality Changes in Receiving Streams

A.A. Aquatic Research Limited

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PROCEDURES AND METHODS FOR EVALUATING WATER QUALITY CHANGES IN RECEIVING STREAMS

TECHNICAL MANUAL

Prepared for

Alberta Environment

Standards and Approvals Division

by

A.A. Aquatic Research Limited

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1.0 INTRODUCTION

This technical guidance manual provides an example and background information needed in implementing the recommended procedures and methods for evaluating water quality changes in receiving streams. The manual details the information required in developing or reviewing an industrial proponent's application under the Clean Water Act. The information consists of background data, coefficients, and methods for testing the accuracy of results from various methods and procedures. In addition, the efficacy of the procedures for evaluating certain stream and effluent conditions are also described. The information is presented in sequence, reflecting the order of technical activities that should be followed in developing or reviewing a proponent's application. A schematic showing the technical activities needed for evaluating a single-point industrial discharge associated with the permit to construct and licence to operate under the Clean Water Act is present in the handout for industrial projects. The handout can be obtained from Alberta Environment, Standards and Approvals Division, Water Quality Branch.

Users of this manual should recognize that other reports and processes may affect the assessment procedures. For instance, objectives for many water quality parameters and knowledge of coefficients used in mathematical relationships are constantly evolving. Therefore, any objectives or coefficients used in examples should not be applied to real-life situations without first referring to the latest references.

The manual, is based on a format established for a test case. The hypothetical project is a bleach kraft pulp mill with a capacity of 900 air dried tonnes per day (ADt/d), located adjacent to the Athabasca River near the foothills of Alberta. The conditions chosen are typical of a large scale pulp mill operation.

2.0 LEVEL I ANALYSIS

An assessment of an industrial proponents application under the Clean Water Act begins with Level I analysis. The analysis comprises four main tasks. The following describes the background information needed in performing each of the tasks.

2.1 EFFLUENT CHARACTERISTICS

Characteristics of the effluent, proposed for discharge to a receiving stream, must be provided by the proponent. The information submitted must identify the effluent parameters, their concentrations, basis of discharge (continuous or discontinuous), and rates of discharge.

For the purpose of this document, the effluent is assumed to originate from a biological treatment system with the characteristics shown in Table 1.

2.2 RECEIVING STREAM CLASSIFICATION AND CHARACTERISTICS

2.2.1 Stream Classification

The Alberta Surface Water Quality Objectives are currently used to protect the most sensitive user of surface waters. These objectives remain as the primary ambient levels to be maintained in mixing zone analyses. However, in conducting mixing zone analyses, a range of water quality objectives can be used to more appropriately represent the drainage basin or to protect a certain river reach.

Table 1 Summary of effluent and receiving stream chemical characteristics and guidelines

Parameters	Conc. in Effluent	Background Conc. in Receiving Stream	Alberta Surface Water Quality Objectives[2]
BOD_5	78.5 mg/L	1.0 mg/L	min. 5.0 mg/L dissolved oxygen
Non-Filterable Residue	508.0 mg/L	2.0 mg/L	max. 10 mg/L above background
Colour	7000 (TCU)	5.0 (TCU)	max. 30 (TCU) above background
pH	8.0	8.2	6.5 to 8.5
Tetrachloroguaiacol	0.010 mg/L	0.000 mg/L	0.003 mg/L[1] (assumed)
Ammonia	1.72 mg/L	0.10 mg/L	0.02 mg/L unionized as NH_3 (McNeely et al. 1979)

Notes:

1. concentrations in the effluent considered maximum values.
2. maximum effluent flow is 65000 m^3/day or 0.752 m^3/s.
3. [1] based on a 96 hour static bioassay LC_{50} toxicity of 0.32 mg/L for rainbow trout, taken from McKim et al. (1976).

   [2] taken from Alberta Surface Water Quality Objectives, Alberta Environment, Standards and Approvals Division (1977).

Downstream of a proposed effluent discharge point, the receiving stream should be classified according to the existing and future water users. The water users should be documented within a reach of approximately 200 km downstream of the proposed discharge location because large rivers receiving effluents generally have extensive (approximately 300 river widths) mixing zones. Water use information can be obtained from Alberta Environment departments, they include: Planning Division, Pollution Control Division, Water Rights Branch, Standards and Approvals Division, and Fish and Wildlife Division.

Following identification of the water users, appropriate water quality guidelines would then be selected. The guidelines may be obtained from the Alberta Surface Water Quality Objectives in Alberta Environment (1977) or the Environment Canada guidelines reported in McNeely et al. (1979). Both are used for the protection of aquatic life. Guidelines for Canadian Drinking Water Quality by Health and Welfare Canada (1979) apply for protection of potable water. In a situation where water quality at the interprovincial border (Saskatchewan- Alberta) is assessed, basin specific water quality indicators may apply. For the purpose of this manual, it is assumed that the receiving stream has a sport fishery, and the Alberta Surface Water Quality Objectives apply (Table 1).

The background water quality data can generally be obtained from Alberta Environment, Pollution Control Division, NAQUADAT data system. In some cases field sampling may be required to obtain an adequate data base.

2.2.2 Streamflow Characteristics

1. Using a 1:1 000 000 scale map, outline the watershed boundary, key Water Survey of Canada stations, locations of water users, and sub-basins along the mainstem of the receiving stream.

2. Develop stationing for all points of interest along the stream course (Table 2). Kellerhals et al. (1972) have done this for a number of Alberta rivers. Note the locations of inflows and water users (in this example, we have adopted river station 0 km at the outfall).

3. Plot hydrologic data along mainstem on log-log paper (e.g. drainage area, mean annual flow, and points of local inflow versus distance). Provide more detail in the area of the proposed effluent outfall and downstream, where the mixing zone will be important (Figure 1).

Table 2 Locations of importance within the mixing zone

Station (km)	Location	Bank	Importance
0	Windfall	Left	Outfall - Q = 0.75 m^3/s
0	Windfall	-	WSC Station - 7Q10 27 m^3/s
30	McLeod River	Right	Confluence - adds 3 m^3/s to 7Q10
32	Whitecourt	Right	Possible water user
123	Fort Assiniboine	Left	Possible water user
221	Pembina River	Right	Confluence - adds 3 m^3/s to 7Q10
269	Lesser Slave River	Left	Confluence - adds 17 m^3/s to 7Q10
372	Athabasca	Right	Possible water user
372	Athabasca	-	WSC Station - 7Q10 59 m^3/s

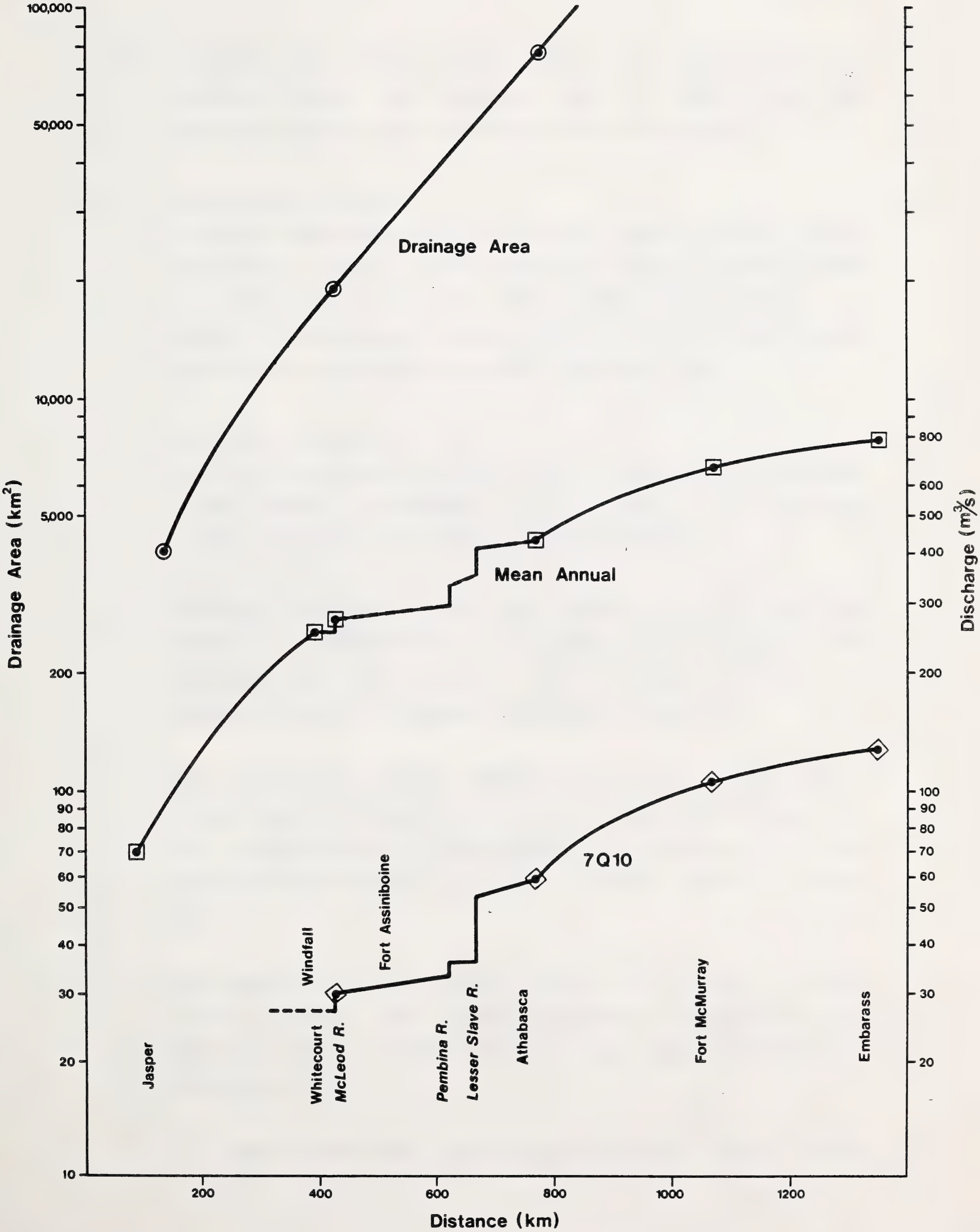


Figure 1 Hydrologic profile – Athabasca River

4. Summarize the monthly stream discharges, temperature, and dissolved oxygen data (Figures 2 and 3). From these, the following important flow conditions can be identified:

   Open Water Conditions

   In August the stream flows are lowest during the high water temperature period and the dissolved oxygen concentrations are almost lowest for the year during this period. In October, the flows are lowest during the open water period while water temperatures are still relatively high.

   Ice Cover Conditions

   In March the flows are lowest for the year. The dissolved oxygen deficit is greatest in the winter, and ice cover inhibits reaeration and photosynthetic processes.

5. Hydrologic analysis should be carried out for each flow condition to determine the 1 in 10 year low flow event for the corresponding 7 day duration. This is termed the 7Q10. An example (ice cover condition) is shown in Figure 4.

   This hydrologic analysis requires frequency analyses of the minimum monthly flows and the minimum daily flows (Figure 4a). This is followed by an interpolation to determine the 7 day duration design event (the 7Q10 = 30 m^3/s shown on Figure 4b).

   This analysis can be easily checked by using a plotting position formula. This simple procedure is illustrated in the following, where the flows for the open water conditions are estimated as well:

   a) Near Windfall there are 24 years of record (1960 to 1983), thus, n = 24.

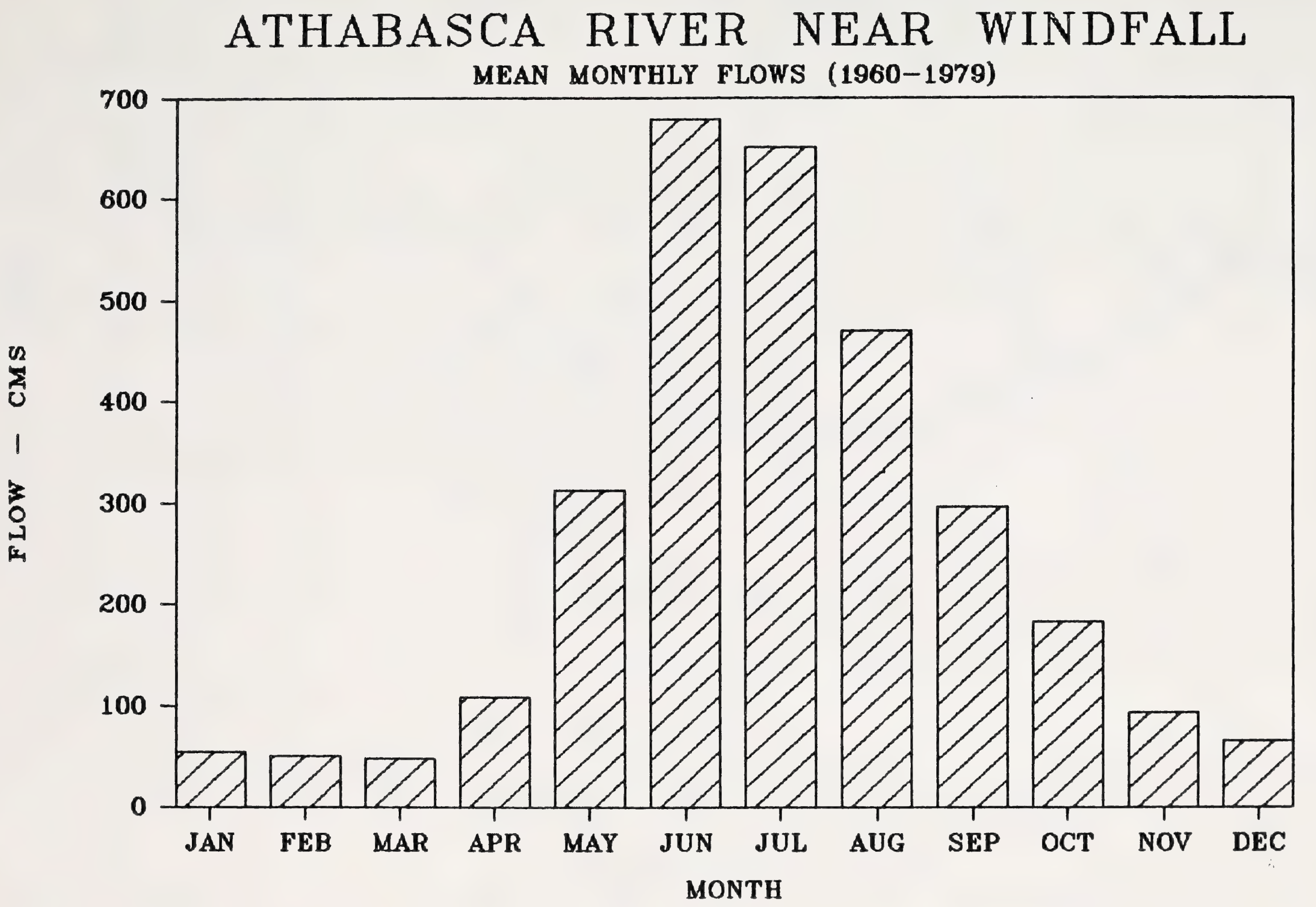


Figure 2 Mean monthly discharges (1960 to 1979) for the Athabasca River near Windfall, Alberta

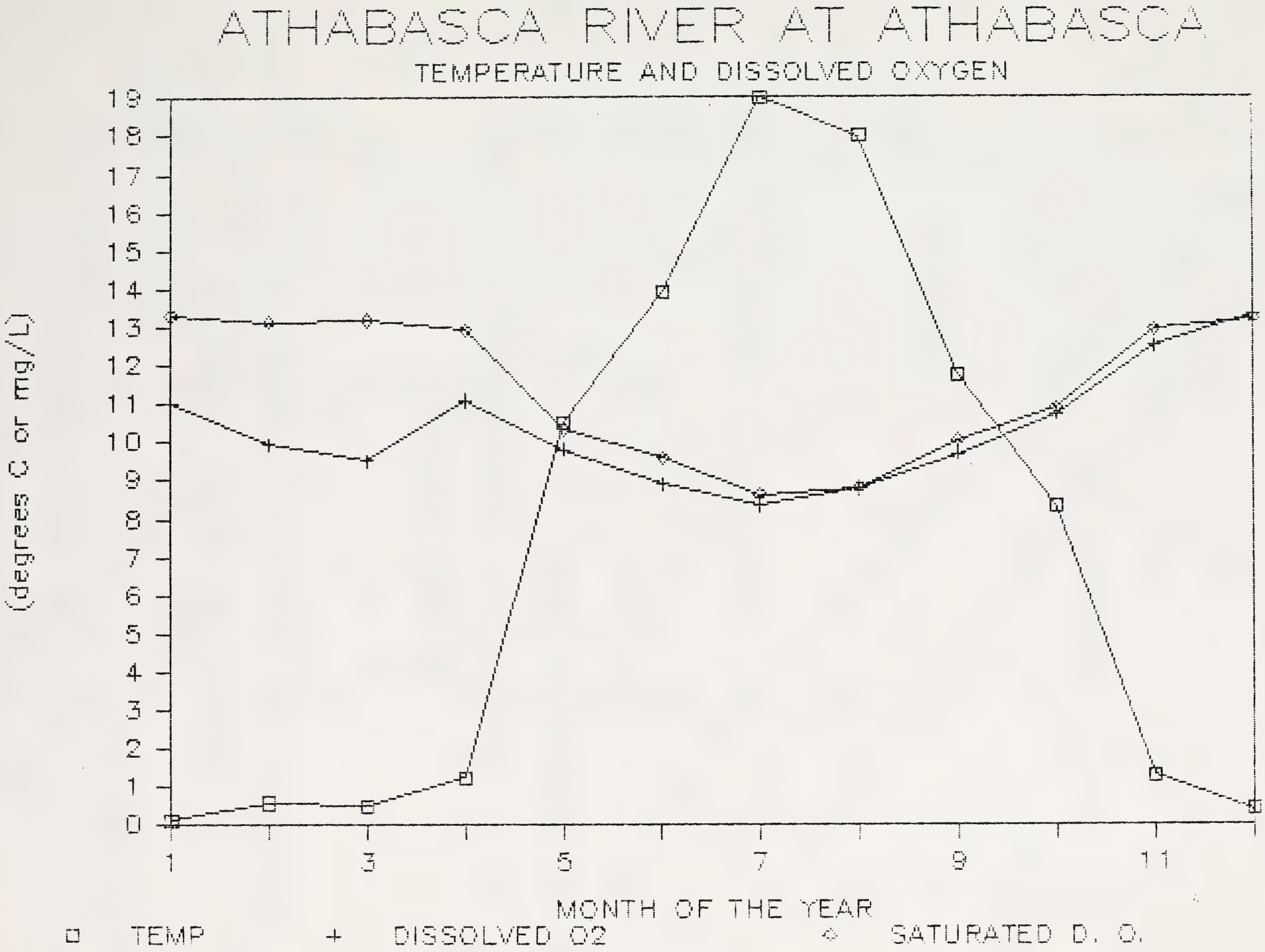


Figure 3 Temperature and dissolved oxygen profiles for Athabasca River

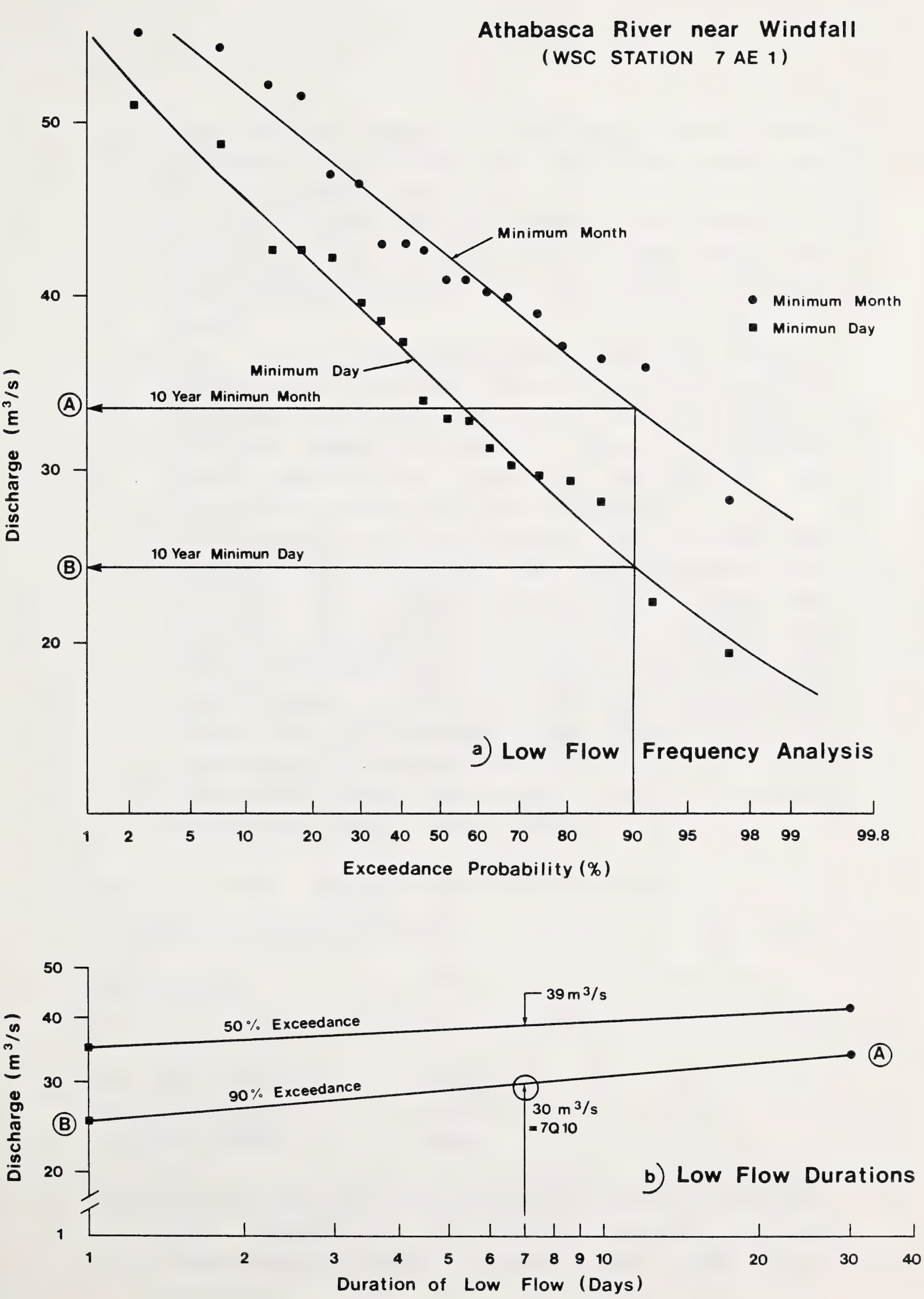


Figure 4 Hydrologic analysis for the Athabasca River

b) Using the Hazen formula: $p = (m - 0.5)/n$, where p is the probability and m is the rank, the 10 year event (i.e. $p = 0.10$) occurs when m is 3.

c) The third lowest flow on record at this station is, therefore, an approximation of the 10 year event. For example, August, 1983 is the third lowest on record (Figure 5).

d) The 7 days of lowest flow during March 1983 reveal an approximation of the 7Q10 during this period (Figure 6). The value (34 m^3/s) is close to the value determined by the more detailed procedure in Figure 4 (30 m^3/s). These procedures are applied to the other two flow conditions to estimate their 7Q10 (Figure 6).

e) The hydrologic profile data indicate that the reach, from Whitecourt to the Pembina River and Athabasca River confluence, has a relatively steady flow. Within this reach of approximately 221 km, the hydraulic and hydrologic conditions can be considered constant for water quality analysis. However, to accommodate the increased drainage area, an adjustment of flows values for the reach is necessary. A value of about 8% is used.

f) The adjusted average flow values for each flow condition are shown in Table 3 and on Figure 1.

Table 3 Average 7Q10 flows downstream of Windfall

Flow Condition	Month	7Q10 (m^3/s)
Open Water (Summer)	August	270
Open Water (Fall)	October	110
Ice Cover (Winter)	March	32

Note: It is important that the hydrologic phenomena be understood when generating the 7Q10 values. However, for water quality analysis, slight deviations in flow values are not important.

ATHABASCA RIVER NEAR WINDFALL - STATION NO. 07AE001

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1960	---	---	---	---	249	707	813	409	228	145	72.3	81.0	---	1960
1961	65.7	57.8	55.1	84.3	317	692	502	399	207	237	128	60.1	235	1961
1962	68.2	53.5	43.2	158	360	614	629	449	294	150	111	136	257	1962
1963	102	57.5	40.9	171	319	634	545	373	291	163	84.6	45.4	236	1963
1964	49.3	54.4	28.1 ←	58.1	247	777	648	477	381	272	103	64.2	264	1964
1965	38.9	41.6	42.8	157	359	895	1 090	678	455	301	151	57.6	357	1965
1966	58.8	65.3	46.5	117	534	595	734	647	369	250	133	77.6	304	1966
1967	47.6	49.6	37.3 ←	45.5	237	855	651	465	287	147	93.3	53.5	248	1967
1968	43.5	35.7	63.2	77.5	249	591	704	485	299	145	75.1	62.6	237	1968
1969	39.8	46.1	45.1	77.0	265	575	468	635	278	153	56.2	40.9	225	1969
1970	47.7	53.2	50.4	92.4	214	632	457	314 ←	155	95.8 ←	57.3	48.7	185	1970
1971	36.4	37.8	39.9 ←	129	296	890	892	486	275	169	79.4	67.0	284	1971
1972	54.0	42.6	70.2	87.1	389	1 030	561	437	276	219	102	71.7	279	1972
1973	56.8	54.2	57.9	131	416	616	484	395	203	170	66.4	63.2	227	1973
1974	50.2	47.8	47.0	164	349	679	636	428	286	172	90.9	66.5	252	1974
1975	48.8	45.5	40.1	72.1	207	441	619	309 ←	189	120 ←	103	50.4	188	1975
1976	48.4	54.2	43.0	128	298	435	634	668	361	172	85.1	62.7	250	1976
1977	53.5	52.5	51.5	90.2	427	676	642	547	367	202	93.8	62.3	274	1977
1978	57.4	53.7	52.0	129	258	685	721	424	484	236	---	---	---	1978
1979	---	---	60.3	92.8	257	544	598	367	231	135	---	---	---	1979
1980	---	---	43.6	136	352	887	523	376	284	200	---	---	---	1980
1981	---	---	58.7	86.5	343	430	504	466	258	119 ←	---	---	---	1981
1982	---	---	43.1	53.7	299	695	939	533	404	248	---	---	---	1982
1983			40.7					355 ←		126				1983
MEAN	53.7	50.2	48.2	106	315	677	652	468	298	184	93.6	65.1	253	MEAN

LOCATION - LAT 54 12 25 N DRAINAGE AREA, 19 600 km²
LONG 116 03 45 W NATURAL FLOW

Note: Data taken from Water Survey of Canada (1983).

a) Hazen formula for probability: p = (m-0.5)/n
where: p = probability
m = rank
n = number of years data

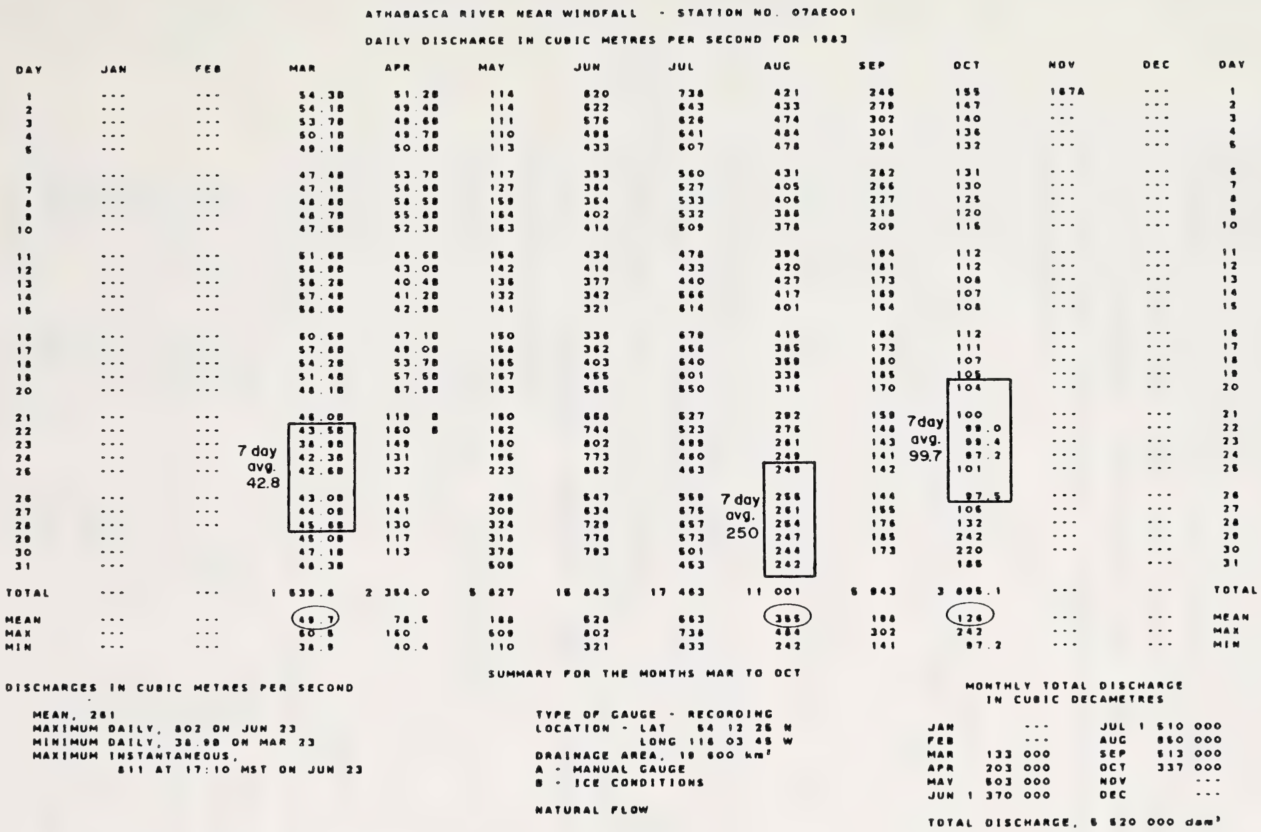
b) Return period (years): t = 1/p = n/(m-0.5)

c) Rank of 10 year event: m = n/t + 0.5 = 24/10 + 0.5 approx. 3 (i.e. 3rd lowest in 10 years)

d) 10 year minimum month:

August	355
October	120
March	40

Figure 5 Simple procedure for frequency analysis



ATHABASCA RIVER NEAR WINDFALL - STATION NO. 07AE001

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR 1983

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	---	---	54.30	51.20	114	820	738	421	246	155	167A	---	1
2	---	---	54.10	49.40	114	622	643	433	279	147	---	---	2
3	---	---	53.70	48.60	111	576	626	474	302	140	---	---	3
4	---	---	50.10	49.70	110	498	641	484	301	136	---	---	4
5	---	---	49.10	50.60	113	433	607	478	294	132	---	---	5
6	---	---	47.40	53.70	117	393	560	431	282	131	---	---	6
7	---	---	47.10	56.90	127	384	527	405	266	130	---	---	7
8	---	---	46.80	56.50	159	364	533	406	227	125	---	---	8
9	---	---	46.70	55.80	164	402	532	388	218	120	---	---	9
10	---	---	47.50	52.30	163	414	509	378	209	116	---	---	10
11	---	---	51.60	46.60	154	434	478	394	194	112	---	---	11
12	---	---	56.90	43.00	142	414	433	420	181	112	---	---	12
13	---	---	56.20	40.40	136	377	440	427	173	108	---	---	13
14	---	---	57.40	41.20	132	342	566	417	169	107	---	---	14
15	---	---	56.60	42.90	141	321	614	401	164	108	---	---	15
16	---	---	60.60	47.10	150	336	679	415	184	112	---	---	16
17	---	---	57.60	49.00	158	362	656	385	173	111	---	---	17
18	---	---	54.20	53.70	166	403	640	359	180	107	---	---	18
19	---	---	51.40	57.60	167	455	601	338	185	105	---	---	19
20	---	---	48.10	67.90	163	585	650	316	170	104	---	---	20
21	---	---	46.00	119 B	180	688	527	292	159	100	---	---	21
22	---	---	43.50	160 B	182	744	523	276	148	99.0	---	---	22
23	---	---	38.90	149	180	802	489	261	143	98.4	---	---	23
24	---	---	42.30	131	196	773	460	249	141	97.2	---	---	24
25	---	---	42.60	132	223	662	463	248	142	101	---	---	25
26	---	---	43.00	145	288	647	559	256	144	97.5	---	---	26
27	---	---	44.00	141	300	634	675	261	155	106	---	---	27
28	---	---	45.60	130	324	729	657	264	176	132	---	---	28
29	---		45.00	117	316	776	573	247	185	242	---	---	29
30	---		47.10	113	376	793	501	244	173	220	---	---	30
31	---		46.30		508		453	242		186		---	31
TOTAL	---	---	1 539.8	2 354.0	5 827	18 843	17 463	11 001	5 943	3 895.1	---	---	TOTAL
MEAN	---	---	49.7	78.5	188	628	563	355	198	126	---	---	MEAN
MAX	---	---	60.6	160	509	802	738	484	302	242	---	---	MAX
MIN	---	---	38.9	40.4	110	321	433	242	141	97.2	---	---	MIN

7 day avg. 42.8

7 day avg. 250

7day avg. 99.7

SUMMARY FOR THE MONTHS MAR TO OCT

DISCHARGES IN CUBIC METRES PER SECOND

MEAN, 261
MAXIMUM DAILY, 802 ON JUN 23
MINIMUM DAILY, 38.90 ON MAR 23
MAXIMUM INSTANTANEOUS,
811 AT 17:10 MST ON JUN 23

TYPE OF GAUGE - RECORDING
LOCATION - LAT 54 12 26 N
LONG 116 03 45 W
DRAINAGE AREA, 19 600 km²
A - MANUAL GAUGE
B - ICE CONDITIONS

NATURAL FLOW

MONTHLY TOTAL DISCHARGE IN CUBIC DECAMETRES

JAN	---	JUL	1 510 000
FEB	---	AUG	950 000
MAR	133 000	SEP	513 000
APR	203 000	OCT	337 000
MAY	503 000	NOV	---
JUN	1 370 000	DEC	---

TOTAL DISCHARGE, 5 520 000 dam³

Note: Data taken from Water Survey of Canada (1984).

a) Monthly flows for August and October are about 1 in 10 year flow values (March values also used to facilitate example).

b) 7Q10 Values:

August $\frac{250\ (355)}{355} = 250$; October $\frac{99.7\ (120)}{126} = 95$; March $\frac{42.8\ (40)}{49.7} = 34$

Figure 6 Simple procedure for 7Q10 estimation

2.2.3 Hydraulic Characteristics

2.2.3.1 Open Water Conditions

1. Plot the surface width (B), the average stream velocity (U), and the hydraulic depth [$H = Q/(U \cdot B)$] as a function of discharge rate (Q) on a log-log plot (Figure 7). Data for this exercise can often be obtained from Kellerhals et al. (1972). Otherwise, information from Water Survey of Canada and field data for various flow measurements must be obtained and processed.

2. Straight lines must be fitted through the data points relating H, U and B to Q in the range of flow rate of interest (i.e. 110 m^3/s to 270 m^3/s):

$$H = K_h \cdot Q^h; \quad U = K_u \cdot Q^u; \quad B = K_b \cdot Q^b$$

Only the exponents (h, u and b) are of interest in this study. These are used to relate reference conditions (HS, US and BS), measured or determined at a reference flow rate (QRS), to other flow rates by the relation: $X = XS \cdot (Q/QRS)^x$. In this relation, X refers to one of H, U or B and x to one of h, u or b. Reference conditions for the Athabasca River are shown in Table 4.

Table 4 Summary of hydraulic characteristics for the Athabasca River

Location	Windfall[1]	Athabasca[2]	Comment
h	0.58	0.55	depth exponent
u	0.38	0.38	velocity exponent
b	0.04	0.07	width exponent
HS	1.47	1.32	reference depth (m)
US	1.25	0.73	reference velocity (m/s)
BS	138	280	reference width (m)
QRS	253	253	[3]reference flow (m^3/s)

[1] Derived from Water Survey of Canada data.
[2] Derived from data in Kellerhals et al. (1972).
[3] Depth, velocity and width are based on the reference flow.

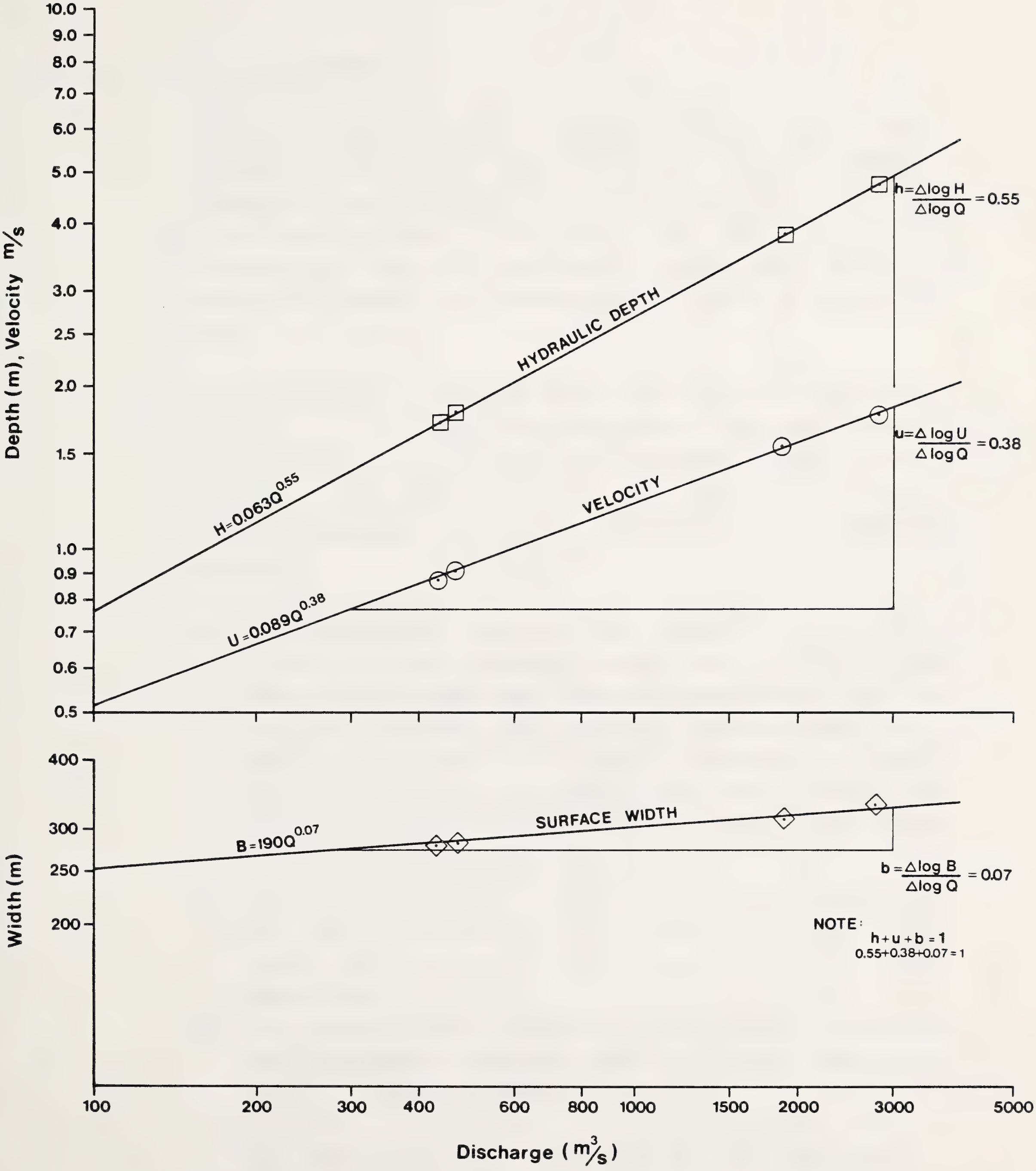


Figure 7 Hydraulic characteristics in the Athabasca River at Athabasca (example only)

2.2.3.2 Ice Cover Conditions

1. Hydraulic characteristics associated with open water conditions differ from those under ice cover conditions because ice cover increases the depth and reduces the velocity of the flow in a river. The depth of flow under ice required to convey the same flow rate as that during open water, is about 30% greater; the corresponding velocity is about 20% less.

2. Hydraulic data are needed for a reference ice cover flow condition. If ice cover flow measurement data are available from Water Survey of Canada, the hydraulic information can be obtained in the same manner as that described in Section 2.2.3.1; otherwise, it can be synthesized in the following manner:

   a) The reference ice cover flow rate should be in the order of the 32 m^3/s, previously established. At this flow rate, the open water flow depth is about 0.44 m. For the ice cover reference flow condition, the hydraulics for a depth of 1.3 x 0.44 = 0.57 m will be determined in detail. The corresponding river width is about 129 m (note: the open water flow condition at this depth would yield a flow of 50 m^3/s and a velocity of 0.68 m/s).
   b) Data on ice roughness is required. Field measurements on the North Saskatchewan River reported in Hodgson and Slater (1984) indicate K_i = 0.078 m; use 0.10 m for this evaluation.
   c) The bed roughness is estimated by calculating it from open water conditions using the logrithmic velocity equation at 50 m^3/s (the river slope is 0.0012).

   Hydraulic Radius: $R = H = 0.57$ m (for open water)

   Shear Velocity: $$U^* = \sqrt{gRS} = \sqrt{9.81(0.57)0.0012}$$

   $$= 0.082 \text{ m/s}$$

Logrithmic Equation: $$\frac{U}{U*} = 2.5 \ln \left[\frac{R}{Kb}\right] + 6.2$$

$$\frac{0.68}{0.082} = 2.5 \ln \left[\frac{0.57}{Kb}\right] + 6.2$$

thus, $Kb = 0.24$ m

(note: Manning's n = $0.038\ Kb^{1/6} = 0.030$)

d) For ice cover conditions, the composite roughness is:

$$K = Kb \left[\frac{1+(Ki/Kb)^{1/4}}{2} \right]^4$$

$$= 0.24 \left[\frac{1+(0.10/0.24)^{1/4}}{2} \right]^4 = 0.16 \text{ m}$$

e) Ice cover conditions are:

Hydraulic Radius: $R = H/2 = 0.57/2 = 0.29$ m

Shear Velocity: $U* = \sqrt{g\ R\ S} = \sqrt{9.81(0.29)0.0012} = 0.058$ m/s

Velocity: $U = U* [2.5 \ln (R/K) + 6.2]$

$$= 0.058\ (2.5 \ln (0.29/0.16) + 6.2) = 0.45 \text{ m/s}$$

Flow: $Q = U\ B\ H = 0.45\ (129)\ 0.57 = 33\ m^3/s$

f) Therefore the reference ice cover conditions at Windfall are:

h = 0.58
u = 0.38
b = 0.04

HS = 0.57 m
US = 0.45 m/s
BS = 129 m
QRS = 33 m^3/s

Using these data, the hydraulic parameters for the desired ice cover flow condition (32 m^3/s) can be approximated.

2.2.4 Estimating Mixing Zone Length

1. The hydraulic parameters for each of the flow conditions, which have been previously determined, are summarized in Table 5.

Table 5 Summary of hydraulic parameters for each flow condition

Flow Condition	Month	7Q10 (m^3/s)	Depth (m)	Velocity (m/s)	Width (m)
Open water (Summer)	August	270	1.53	1.28	138
Open water (Fall)	October	110	0.91	0.91	133
Ice Cover (Winter)	March	32	0.56	0.44	129

2. Estimate dispersion parameter Ez and its range for each of the flow conditions using the relation:

$$Ez = Kz\ H\ U^*$$

where: Ez is the transverse mixing (dispersion) coefficient (m^2/s)

Kz is a dimensionless mixing coefficient (a constant for the reach)

H is the hydraulic depth (m); this applies for both open water conditions and for ice cover conditions

U* is shear velocity (m/s)

The values for Kz must be estimated based on similarities of the study reach to other reaches where field data are available. The accuracy to which Kz can be estimated for a given reach is not very precise. As a result, sensitivity analysis for the mixing zone length estimates are based on the Kz parameter. For the Athabasca River near Windfall, Kz could range from 0.5 to 1.2 (estimated) under ice cover conditions and between 0.4 and 0.8 (estimated) for open water conditions (Table 6). From these estimated Kz values, the shear velocity and the hydraulic radius, Ez values for the various flow conditions can be estimated (Table 7).

Table 7 Estimated Ez values for Athabasca River near Windfall

Flow Condition	U* (m/s)	Ez (m^2/s)		
		Low	Average	High
Open Water (Summer)	0.134	0.082	0.123	0.164
Open Water (Fall)	0.104	0.038	0.057	0.076
Ice Cover (Winter)	0.057	0.016	0.027	0.038

Note: Based on river slope of 0.0012 m/m.

3. Mixing zone length can be established from the equation:

$$X_m = \frac{\emptyset B^2 U}{Ez}$$

where: X_m is the mixing zone length (m)
$\emptyset$ is the dimensions mixing zone length parameter (see note below)
B is width of river (m)
U is velocity of river (m/s)
Ez is transverse mixing coefficient (m^2/s)

Table 6 Summary of field dispersion tests in Alberta

Site	Flow $Q(m^3/s)$	Width B (m)	Depth H (m)	Velocity U(m/s)	Slope S(m/m)	Ez (m^2/s)	Kz
Ice Cover							
Beaver River near Beaver Crossing	6.54	38.7	0.61	0.28	0.00021	0.020	2.54
Lesser Slave River	27.8	36.3	2.07	0.37	0.00011	0.012	0.35
Athabasca River below Athabasca	105	276	0.96	0.40	0.00029	0.010	0.56
Athabasca River below Fort McMurray	240	252	1.92	0.49	0.00023	0.041	1.16
Open Water							
Beaver River near Beaver Crossing	20.5	42.7	0.96	0.50	0.00021	0.043	1.01
Lesser Slave River	71	43.0	2.53	0.65	0.00011	0.041	0.33
Bow River at Calgary	109	104	1.00	1.05	0.00180	0.085	0.61
North Saskatchewan River below Edmonton	142	156	1.54	0.59	0.00035	0.022	0.17
North Saskatchewan River below Edmonton	192	213	1.55	0.55	0.00035	0.031	0.25
Athabasca River below Athabasca	566	320	2.05	0.86	0.00029	0.067	0.41
Athabasca River below Fort McMurray	776	373	2.20	0.95	0.00023	0.093	0.75

Note: Taken from Beltaos (1976), Beltaos and Anderson (1979), Lau and Krishnappan (1977).

note: The Ø value is reported in Gowda (1980). The mixing zone is the distance to the cross section where the local concentrations vary by no more than some % from the mean concentration for that particular cross section. If mixing is at the 5% variation level (i.e. $0.95 \leq CR \leq 1.05$) then Ø = 0.4 (Gowda 1980). With this definition Ø is constant in all analyses.

Thus:
$$X_m = \frac{0.4\ B^2\ U}{Ez}$$

The following mixing zone lengths were based on the transverse mixing coefficients given in item 2 and flow conditions in item 1 (Table 8).

Table 8 Mixing zone lengths for each flow condition in the Athabasca River downstream of Windfall

Flow Condition	Mixing Zone Length (Km)		
	High	Estimate	Low
Open Water (Summer)	119	79	59
Open Water (Fall)	169	113	85
Ice Cover (Winter)	183	108	77

The estimated mixing zone lengths are all less than the length of the reach for which the hydraulic and hydrologic conditions were estimated (i.e. the 221 km reach from Windfall to the mouth of the Pembina River).

2.3 DILUTION ANALYSIS

Before the supplementary information on dilution analysis is detailed, it is important to realize that the selection of any method used for assessing a receiving stream, requires a trade-off between system realism and analytical efficiency. Delos et al. (1984) reported that the simplest methods are often dependent on a few critical assumptions; the technical issues and uncertainties are generally few in number but could be intractable in nature. Complex analyses however, with their numerous input parameters, require the support of considerable laboratory and field data. The complex methods are applicable to a wider range of questions than the simpler methods. It is usually more efficient to select methods in stages, starting simply and then proceeding to greater levels of complexity as the issues, costs, benefits and decision needs evolve.

The selection of a method must be made on the understanding that many factors determine the concentrations of parameters in a receiving stream, these include:

- mixing of effluent and upstream waters,
- partitioning between dissolved and particulate (total) forms in both the water column and the sediment,
- exchange between the water column and the sediment,
- decay by irreversible chemical transformation,
- losses by burial and volatilization, and
- downstream transport via stream flow and bed load.

A dilution calculation in Level I analysis, is the first process normally used in predicting ambient concentrations of parameters. The formulation assumes that mixing is relatively rapid and decay or settling is low compared to mixing (the importance of mixing can be determined from the procedures in Section 2.2.4). The calculation predicts the concentration of a parameter at the point where mixing is complete. It does not indicate the location of complete mixing nor the concentrations within the mixing zone. Therefore, the main disadvantage of dilution calculations at the point of discharge is that they do not indicate the complete nature of the situation.

The dilution formulation can be used for conservative and non-conservative parameters. Conservative parameters are those that do not decay, become consumed in biological processes or settle from the water column. Chloride is an example of a conservative non-degradable substance with little tendency to precipitate or adsorb to sediment and its concentration in a stream determined only by dilution. Non-conservative parameters like priority pollutants, may undergo a wide range of processes. The organics are subject to degradation, and transfer to the atmosphere and sediment. Metals (as total metal) do not degrade but can undergo transformations to other species; they also have an affinity for sediment (Forstner and Wittmann 1979). Priority pollutants and particularly the dissolved fractions of a pollutant, should not be regarded as conservative pollutants since adsorption can be a rapid process (Delos et al. 1984). The authors however, indicated that where the spacial distance under study is very small, conservative assumptions may be appropriate for the total form of most pollutants. They indicate that it is customary to consider behaviour within mixing zones to be conservative, since the time of passage is so small. The investigator must consider each situation independently based on the kinds of parameters studied.

2.4 DISSOLVED OXYGEN ANALYSIS

In the Level I analysis, dissolved oxygen evaluation can be conducted by using the Streeter Phelps oxygen sag equation or by a micro-computer model such as the one described in this manual. The computer model provides the added advantage of using more site specific information, and therefore, the results are more accurate than those obtained from the Streeter Phelps equation.

The model is a one-dimensional simulation based on the Streeter Phelps dissolved oxygen sag equation. The model considers the hydraulic characteristics of the stream, and the effluent quality and quantity. The model's data input and the output of results are part of an interactive process detailed in Table 9.

Table 9 Sequence of data input and output of results for the dissolved oxygen model DOANAL

A. River Conditions:

Variable	Units	Description
QR	m^3/s	river discharge upstream of outfall
U	m/s	average river velocity
H	m	hydraulic depth of river
T	°C	river temperature upstream of outfall
E	m	average elevation of river in reach

The model outputs the saturated dissolved oxygen concentration in the river which has been corrected for temperature and elevation.

DOU	mg/L	dissolved oxygen upstream of outfall
BODU	mg/L	ultimate BOD level upstream of outfall

B. Effluent Conditions:

QE	m^3/s	effluent discharge rate
DOE	mg/L	dissolved oxygen level in effluent
BODE	mg/L	ultimate BOD level in effluent
TE	°C	temperature of effluent
K1	1/day	decay rate for BOD (base e)

The model outputs the concentrations of parameters immediately downstream of the outfall (assuming complete mixing). These include temperature, saturated dissolved oxygen, actual dissolved oxygen, dissolved oxygen deficit, and the ultimate BOD. The distance travelled in five days is given for consideration of carbonaceous BOD (this type of simulation is relevant in this time frame).

C. Reaeration Constant:

The reaeration rate constants (for both 20°C and for the mixed temperature conditions) are estimated using equations of Churchill, O'Connor, and Owen. These equations have been suggested by USEPA in Driscoll et al. (1983) for certain ranges of hydraulic conditions in a river. The appropriate equation is identified by the model. The model user can then select the results of one of these equations or input another more appropriate constant. For a user determined value, K2 must then be inputed as follows:

K2	1/day	reaeration rate coefficient (base e).

D. BOD Decay Rate:

The model outputs the temperature corrected BOD decay rate for the reach downstream of the outfall. The user can use the decay rate in the model or input another value. For a user determined value, K1 must be inputed as follows:

K1	1/day	decay rate for BOD (base e)

The model then determines the dissolved oxygen concentration profile. The profiles will be based on one of three possible cases:

1) the classic Streeter Phelps profile with a dissolved oxygen sag point;
2) reaeration occurs at a greater rate than deoxygenation (in this case the river reaerates until oxygen saturation is reached);
3) the oxygen depletion rate is greater than the reaeration rate; in this case the dissolved oxygen concentration declines until either the oxygen or the BOD is depleted (this is typical of ice cover conditions).

For the classic Streeter Phelps condition (case 1), the river conditions immediately downstream of the outfall and at the sag point are given. For the latter two cases (cases 2 and 3), the model user is requested to identify the distance downstream of the outfall to be simulated.

X	km	specified simulation distance

E. Profiles:

Profiles of BOD, dissolved oxygen deficit, and dissolved oxygen comprise the output results. The profile distance is either user defined (as for cases 2 and 3) or, in the case of the classic Streeter Phelps sag curve, three times the distance to the sag point.

For the Level I dissolved oxygen analysis, the Athabasca River input data are summarized on Table 10. The input and output from the microcomputer model is described in Appendix A of this manual. A summary of the results for the flow conditions analyzed is presented on Table 11. In this example, only dissolved oxygen profiles for Cases 2 and 3 occur; the Streeter Phelps dissolved oxygen sag curve does not occur. In all conditions, the dissolved oxygen level does not decrease below 5.0 mg/L.

The results of dissolved oxygen analysis are most sensitive to the stream reaeration rate (K2) and the BOD decay rate (K1). The recommended procedure in Level I studies is to use the equations of Ownes, Churchill and O'Connor as outlined in Driscoll et al. (1983).

Ownes (1964) $K2 = 5.34\ U^{0.67}/H^{1.85}$
Churchill (1962) $K2 = 5.02\ U^{0.97}/H^{1.67}$
O'Connor (1958) $K2 = 3.88\ U^{0.5}/H^{1.5}$

Although field tests are the best means to determine K2, they are generally too expensive to conduct as part of Level I analyses. The correlations for the various regression equations for K2 are not high. As a result, values determined from these have the potential to overestimate K2. It is suggested that the value of K2 used in the dissolved oxygen model be less than half that predicted by any of the USEPA regression equations.

The BOD decay rate can be determined from laboratory analysis of the effluent or by using analytical results from other plant discharges. If the BOD decay rate is known with a high degree of confidence, then sensitivity evaluations for the dissolved oxygen analysis results associated with variations in K1 are not necessary. However, where uncertainity exists, or where the stream has an ice cover, the variation of K1 should be examined in a similar fashion as for K2 (i.e. examine the effect of an increased K1). In the case of ice cover conditions, the temperature correction equations for K1 are least accurate and multiplying K1 by a factor of 2 would be reasonable.

Table 10 Dissolved oxygen analysis

Parameter	Summer	Fall	Winter
River:			
QR (m^3/s)	270	110	32
U (m/s)	1.28	0.91	0.44
R (m)	1.53	0.91	0.56
T (°C)	20.0	9.0	0.5
E (m)	670	670	670
DOU (mg/L)	8.0	10.2	9.2
BODU (mg/L)	1.7	1.7	1.7
Effluent:			
QE (m^3/s)	0.752		
DOE (mg/L)	0.0		
BODE (mg/L)	133.5		
TE (°C)	20.0		
K1 (1/day)	0.175 @ 20°C (base e)		
Reaeration Rates:			
Surface Condition	Open Water	Open Water	Ice Cover
K2 (1/day)	1.0	1.0	0.0

Table 11 Results of Level I dissolved oxygen analysis

	Open Water		Ice Cover
	Summer	Fall	Winter
Oxygen profile case	2	2	3
Distance travelled in 5 days (km)	553	393	190
Mixed temperature (°C)	20.0	9.1	1.0
Saturated dissolved oxygen (mg/L)	8.45	10.68	13.03
Mixed oxygen level d/s of outfall (mg/L)	7.98	10.13	8.99
Greatest oxygen deficit (mg/L)	0.47	0.55	7.11
Lowest oxygen level (mg/L)	7.98	10.13	> 5.00
Location of greatest deficit	d/s outfall	d/s outfall	> 400 km

Note: d/s - downstream

3.0 LEVEL II ANALYSIS

The Level II analysis consists of an advanced dissolved oxygen (DO) analysis and a detailed mixing zone evaluation (MIXAPPLN model).

3.1 DISSOLVED OXYGEN ANALYSIS

The Level II dissolved oxygen analysis is undertaken when Level I analysis identifies oxygen deficiences (i.e. < 5.0 mg/L) in the receiving stream. In Level II analysis, the DO Model (DOANAL) is recommended. This method is similar to that described in Level I. The improved accuracy of Level II compared to Level I is due to some changes in the input data. As described in Section 2.4, the results of the DO analysis are most sensitive to BOD decay rate (K1) and the stream reaeration rate (K2). Level II analysis requires that laboratory analysis be conducted to determine (K1) and that field testing be completed to aid in determining (K2). Field testing should include measuring river cross sections and velocity distributions throughout the reach to the sag point. The same regression equation and reductions suggested in Level I also apply in this case. A test case evaluating DO in a receiving stream reported in Driscoll et al. (1983) can be used to exemplify the Level I and Level II analysis. In addition, the authors described basic concepts, and the application of BOD/DO equations and models.

3.2 MIXING ZONE ANALYSIS

The Level II mixing zone analysis (MIXAPPLN model) is initiated when the concentrations of effluent parameter(s) exceed the water quality objectives downstream of the outfall. The basic objective is to delineate the mixing zone and the degree of non-compliance.

The MIXAPPLN model can be used to assess total form, conservative and non-conservative parameters. It should be realized however, that with non-conservative parameters, there are internal source/ sink reactions that may greatly affect the concentration of the parameters in a receiving stream. The MIXAPPLN model accounts for these reactions in the K value; these are termed RBK and RKS in the model. The K value is an aggregate first-order decay rate coefficient, the result of the combined effects of transport and transformation forces acting on the parameter with distance (or time-of-travel) downstream from the discharge. Delos et al. (1984) reported that the decay coefficient is both site and time specific; varying with changes in flow, cross-sectional geometry, solids concentration, aquatic vegetation, temperature, sunlight, and pH. Therefore, great care must be taken when applying this model to a specific site without enough field data to confirm the validity of the aggregate decay rate coefficient. Where sufficient field data are available, K is adjusted until the calculated concentrations reasonably match the measured concentration along the length of the river downstream of the effluent discharge point.

Although this method is somewhat data intensive, it is fairly straightforward. The main limitation is that it does not reveal the factors that control K. Delos et al. (1984) reported that there is little experience to indicate reasonable values for decay rates of most priority pollutants. In situations where identification of individual factors controlling K (i.e. loss to sediment, biological uptake, partitioning, etc.) are required, a more complex model is required. Such assessments are considered part of Level III analysis.

For use in analytical models (such as MIXAPPLN), the value for Ez should be multiplied by the shape velocity factor. The shape velocity factor is a function of the variability of the flow depth and velocity across the channel. Procedures for estimating this factor are given in Beltaos (1978). Values for natural streams typically range from 1.0 to 3.0. In Level II analysis, field tests should be conducted to determine the shape velocity factor.

3.3 MIXAPPLN - TRANSVERSE MIXING PROGRAM

The MIXAPPLN model is a computer simulation of two dimensional mixing of effluents in receiving streams. Descriptions of the model, and the hydraulic and water quality data needed for proper application have been presented by Gowda (1980). To facilitate its utilization, the model has been modified to provide a clearer description of its input requirements and to aid in interpreting the output. This model is stored on the MTS system at the University of Alberta as file MIXAE.

The MIXAPPLN model has a fairly simple data file structure (Table 12). The project title and receiving stream reference coefficients are input on the first two lines. The receiving steam is subdivided into a number of uniform reaches (whose downstream limits are called transects) for which the hydraulic and mixing characteristics are input on lines 3 and 4 (note that line 3 is repeated for each transect). A variety of runs can be made by data input on line 5 (stream flow rate), line 6 (stream temperature), and line 7 (effluent flow rate). Lines 8 and 9 refer to input requirements for the analysis of ammonia. Line 10 relates to the effluent discharge, location, concentration, and other water quality considerations. Finally, line 11 is input for the decay rates of each reach in the system.

Table 12 File structure for the MIXAPPLN program

Line	Format	Variable	Units	Description
1	20A4	TITLE	--	include stream name and pollutant
2	5F5.2, I2	QRS	m^3/s	reference stream flow rate for transect data
		BPWR	--	width exponent (power - in the order of 0.0 to 0.2)
		HPWR	--	depth exponent (power - in the order of 0.4 to 0.6)
		UPWR	--	velocity exponent (power - in the order of 0.3 to 0.4)
		TEMPS	°C	reference temperature for decay rates (usually 20°C)
		NTR	--	number of transects downstream of outfall (max = 10)
*** repeat line 3 for each transect (i.e. NTR times) ***				
3	4F8.2	X	m	longitudinal distance below outfall to transect
		BS	m	reference width at transect
		HS	m	reference depth at transect
		US	m/s	reference mean velocity of transect
4	10F8.4	EZ	m^2/s	reference transverse mixing coefficient at each transect (NTR values)
5	I2, 5F5.2	MQ	--	number of upstream flows for design case (max = 6)
		QRUP	m^3/s	streamflow rates upstream of outfall (MQ values)
6	I2, 5F5.2	MT	--	number of design case temperatures (max = 6)
		TMP	°C	temperature of river (MT values)
7	I2, 5F5.2	MF	--	number of design case effluent flows (max = 6)
		QEFL	m^3/s	effluent flow rates (MF values)
8	F2.1	AMONIA	--	Enter 1 if analysis is for ammonia Enter 0 if analysis is not for ammonia
*** include line 9 only if AMONIA = 1 (i.e. analysis for ammonia) ***				
9	I2, 5F5.2	MPH	--	number of design case pH values (max = 5)
		PH	--	pH of stream water (MPH values)
10	7F8.2	QCP	m^3/s	cumulative flow between bank & outfall (point discharge)
		CEFL	mg/L	effluent concentration
		CBKG	mg/L	background concentration in river
		CS	mg/L	specified instream water quality objective
		THETA	--	temperature correction coefficient
		RBK	1/day	decay rate coefficient for background at TEMPS (base e)
		XWCP	m	downstream distance to nearest critical water user
11	8F10.3	RKS	1/day	decay rate coefficient for reach at TEMPS (NTR values - base e)

Notes:
1. This version of MIXAPPLN is a revised version of Gowda (1980) by the authors.
2. Units for parameter concentrations may be different (e.g. ug/L) if they are used consistently.

MIXAPPLN provides more than just a simulation of the effluent mixing in the stream course (an example of MIXAPPLN output file is located in Appendix B). It reveals the sensitivity of the results to various conditions. For example, the seasonal variation of the mixing zone length and the impacts of various treatment alternatives (in terms of effluent discharge rate and quality), can be compared based on the Limited Use Zone (LUZ) concept in the mixing zone (Figure 8).

The user of MIXAPPLN must examine the Critical Point Method Results for each run to assess the impact of the effluent discharge. The LUZ is the maximum width of the river (in terms of flow) where parameter concentrations above the allowable limit (CS) can be tolerated. The distance (XL) to the point of maximum concentration (CL) along the LUZ boundary is shown. An analytical procedure is then carried out to determine the maximum allowable effluent concentration (CEA) and the distance (XSCEA) to the section downstream where the shoreline concentration on the outfall side of the river becomes equal to the allowable limit (CS).

The MIXAPPLN model uses a large number of variables to describe the important parameters in the effluent discharge analysis. To aid in the understanding of these, a glossary of the variables is provided (Table 13). As a further aid, Figure 9 shows how the program estimates the allowable effluent discharge concentration in order to satisfy the LUZ criteria. The example illustrates the case when the concentration of the effluent exceeds its maximum allowable concentration (the longitudinal concentration profiles are shown by the solid lines). The model iterates through the analytical process to determine the allowable effluent concentration (longitudinal concentration profiles shown by the broken lines).

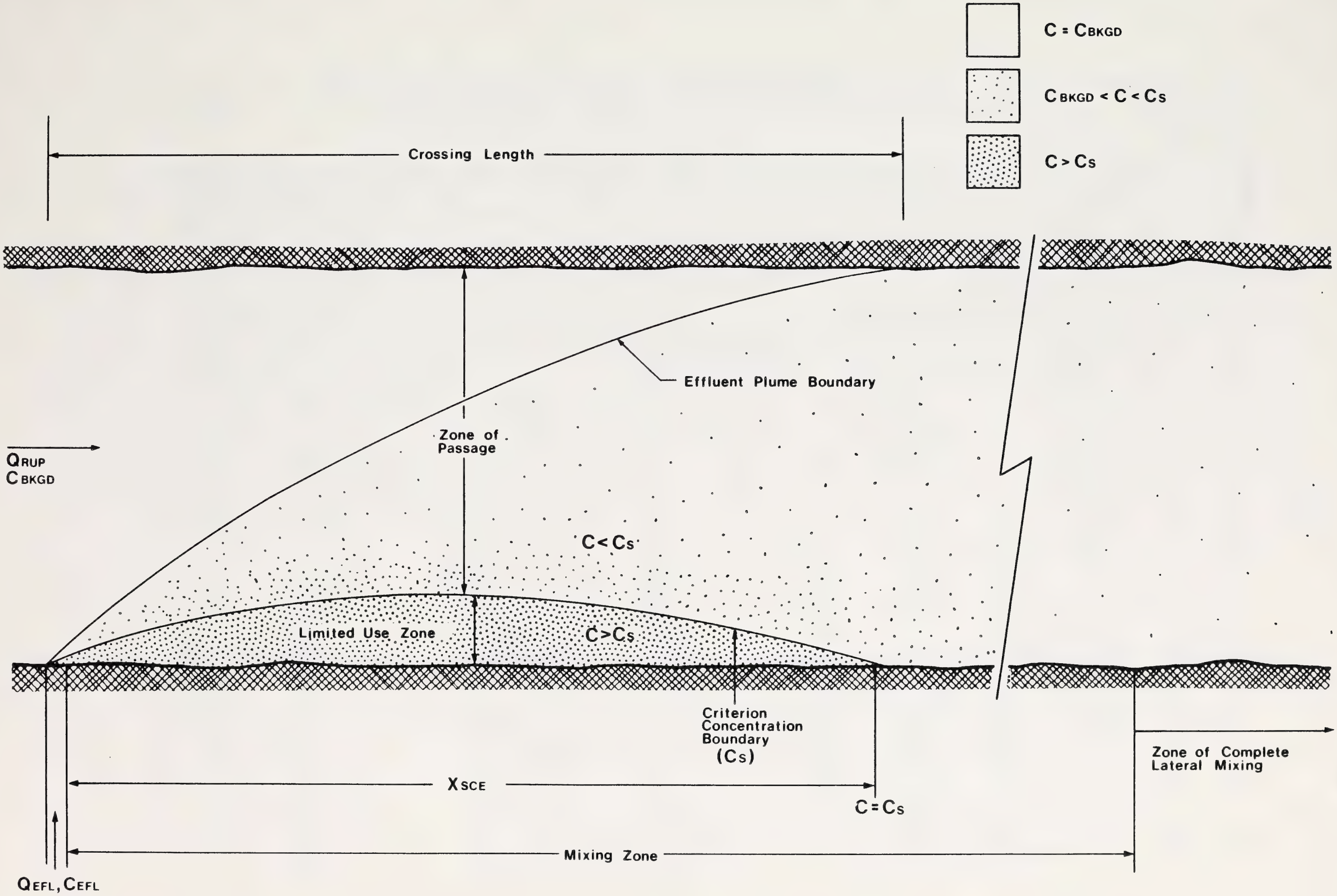


Figure 8 Characteristics of the mixing zone

Table 13 Summary of variables for the MIXAPPLN model

Variable	Description
BPWR:	width exponent, bex (in the order of 0.0 to 0.2)
BS:	reference width (m) at transect i (at flow = QRS)
BW:	weighted mean value of width (m) for the reach of river between the outfall and transect i
C:	concentration at a particular location (X, QZ/QT) in the river
CA:	completely mixed instream concentration just below outfall
CAVG:	cross sectional average concentration at transect i
CAWP:	cross sectional average concentration at downstream boundary (X = XWCP)
CBKG:	background concentration in river
CEA:	maximum allowable concentration of pollutant in effluent that can meet instream standards of CS for an LUZ that is QZ/QT wide
CEFL:	effluent concentration of pollutant for design case
CL:	concentration at critical point (for a selected QZ/QT, LUZ criterion) when CEFL is still used
CMZ:	concentration at downstream end of mixing zone
CS:	specified instream water quality objective (with analysis of ammonia, this is un-ionized objective)
CUI:	concentration of un-ionized ammonia (for pollutants other than ammonia, CUI values are set to zero)
EZ:	tranverse mixing (dispersion) coefficient (m^2/s)
HPWR:	depth exponent, hex (in the order of 0.4 to 0.6)
HS:	reference mean depth (m) at transect i (at flow = QRS)
HW:	weighted mean value of depth (m) for the reach of river between the outfall and transect i
ITRN:	number of iterations
LUZ:	limited use zone (between outfall bank and selected QZ/QT); region of river where C > CS
MF:	number of design case effluent flow values
MPH:	number of design case pH values
MQ:	number of design case upstream flow rate values
MT:	number of design case temperature values
NTR:	number of transects downstream of outfall
PH:	pH of river water for design cases
QCP:	cumulative discharge (m^3/s) between bank and outfall location in the cross-section (e.g. QCP = 0.0 for a bank outfall; QCP = (QRUP + QEFL)/2 for a midstream outfall)
QEFL:	design case effluent flow rates (m^3/s)
QRS:	reference streamflow rate just below outfall (m^3/s)
QRUP:	streamflow rates just upstream of outfall for the design cases (m^3/s)
QT:	total river discharge (m^3/s)
QZ:	partial cumulative discharge (e.g. QZ = 0 at right bank or outfall; QZ=QT at left bank) in m^3/s
QZ/QT:	lateral distance across river, expressed as: partial cumulative discharge/total discharge (e.g. QZ/QT = 0 at right bank; QZ/QT = 1 at left bank)
RBK:	decay rate coefficient associated with CBKG at the temperature, TEMPS (per day, to base e)
RBT:	decay rate coefficient associated with CBKG at the given stream temperature, TMP (per day, to base e)
RKS:	decay rate coefficient for reach, i at the reference temperature, TEMPS (per day, to base e)
TEMPS:	reference temperature at which decay rates are known (usually 20°C)
THETA:	temperature correction coefficient, 0
TITLE:	title of study (river, flow and effluent condition, etc.)
TMP:	temperature of river water for design cases (°C)
UPWR:	velocity exponent, uex (in the order of 0.3 to 0.4)
US:	reference mean velocity (m/s) at transect i (at flow = QRS)
UW:	weighted mean value of velocity (m/s) for the reach of river between the outfall and transect i
X:	longitudinal distance below outfall to a given transect i (m)
XL:	distance (m) below outfall to the critical point (for a selected QZ/QT, LUZ criterion) when allowable effluent concentration (CEA) is being estimated (note: for location XL, QZ/QT the concentration will be CS with CEA as the effluent)
XMZ:	mixing zone length (i.e. the distance to the point where the concentration at any point in the transect is within 5% of the average)
XSCE:	maximum longitudinal spread along shoreline at which C > CS when effluent concentration is CEFL
XSCEA:	maximum longitudinal spread along shoreline at which C > CS when effluent concentration is CEA
XWCP:	longitudinal distance to limiting downstream boundary (e.g. critical water user)

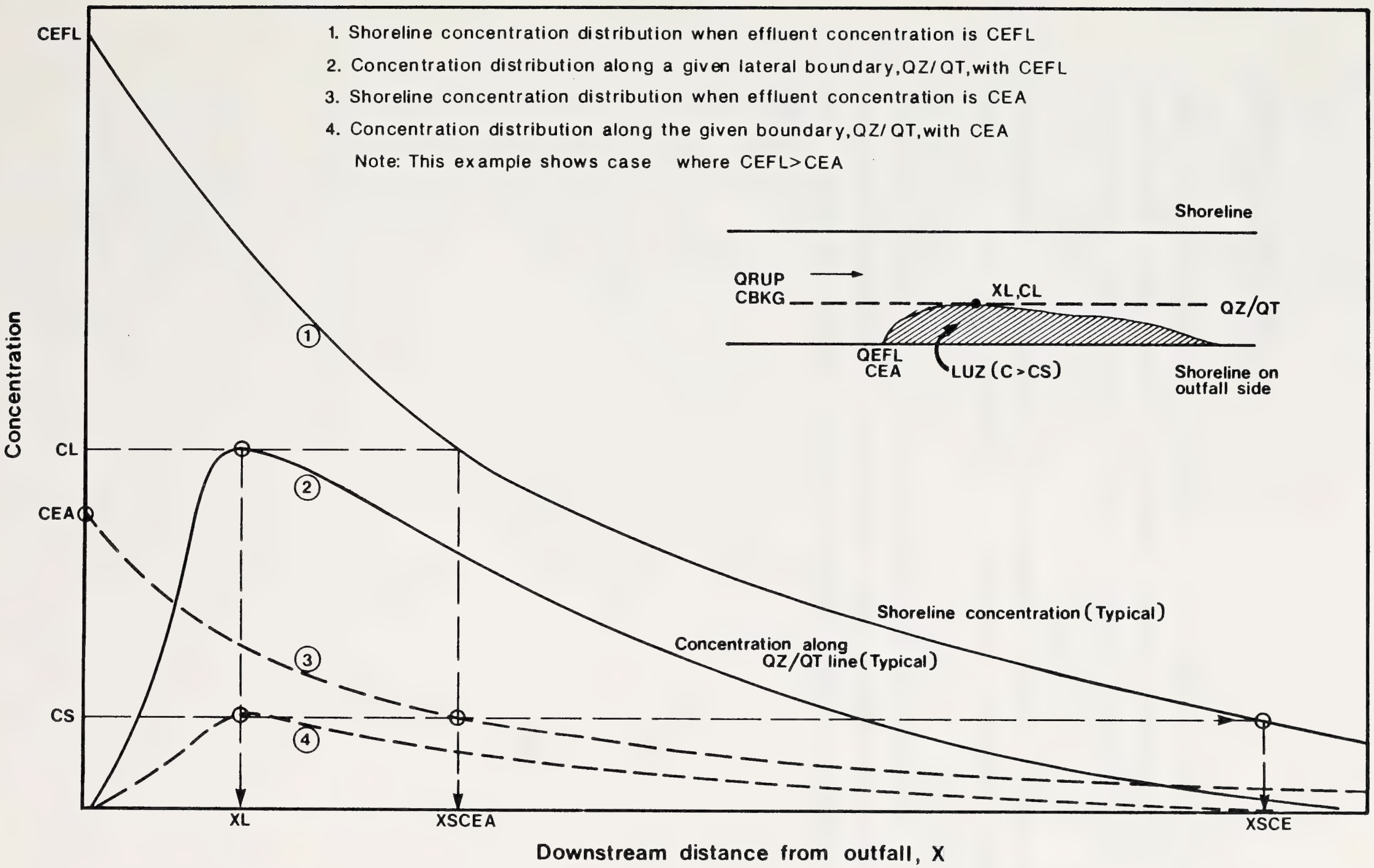


Figure 9 Graphical representation of iterative procedure to determine the allowable effluent discharge concentration

4.0 LEVEL III ANALYSIS

Level III analysis also referred to as special studies may be required by a proponent to further define the impacts of those water quality parameters of concern. The nature and scope of such studies should be initiated through negotiations with Alberta Environment. Because of the specific nature of each special study, it is not practical to establish rigorous assessment procedures as with Levels I and II studies. However, most problems that are considered candidates for special studies can be assessed using models. These models include DOSAG-111, SNOSC 1, Qual I, Qual II, WQRRS, RECEIV, SRMSC1, WASP, EXPLORE 1, and HSPF.

5.0 CONCLUSIONS

The technical manual provides an example and background information needed in implementing the recommended procedures and methods for evaluating water quality changes in receiving streams. The manual is based on a hypothetical case where an effluent from a pulp mill is discharged into the Athabasca River. The information is present in sequence reflecting the order (Levels I to III) of technical activities that should be followed in developing or reviewing an industrial proponent's application under the Clean Water Act.

In Level I analysis, the information consists of background data including effluent and stream characteristics, and water quality guidelines. Data that must be determined mathematically, i.e. hydrologic and hydraulic parameters, and coefficients are also described. The importance of these values as input variables in determining the extent of the mixing zone is outlined in detail. Some simple calculations as means of testing the accuracy of the results are described. The efficacy of the procedures (i.e. dilution analysis) for evaluating certain stream and effluent conditions are outlined. The conservative and non-conservative behaviours of potential pollutants are also described as a means of defining the accuracy of the results. The input data and output results for the dissolved oxygen model were also outlined in detail as part of the Level I analysis.

In Level II analysis, broadening of the information base on the MIXAPPLN model is the main focus. The model is described in terms of its structure, limitations, application on conservative and non-conservative water quality parameters, input data, and evaluation of output results. The importance of determining the K value is also outlined. In Level III analysis, models that can be used on specific studies are identified.

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APPENDIX A

DISSOLVED OXYGEN ANALYSIS

COMPUTER OUTPUT

```
*** DOANAL -- DISSOLVED OXYGEN ANALYSIS -- STANDARD VERSION ***
      *** VERSION 1.1 -- JULY 1985 -- BY JOHN HODGSON ***

     TITLE.....? ATHABASCA RIVER D/S WINDFALL -- SUMMER

     A. RIVER CONDITIONS
     *******************

     RIVER DISCHARGE (m3/s)..................................? 270
     AVERAGE RIVER VELOCITY (m/s)............................? 1.28
     HYDRAULIC DEPTH (m).....................................? 1.53
     TEMPERATURE IN RIVER U/S OF OUTFALL (degrees C).........? 20.0
     AVERAGE ELEVATION OF REACH (m)..........................? 670

     NOTE: Saturated dissolved oxygen level upstream is  8.45 mg/L
           (corrected for temperature and elevation)

     DISSOLVED OXYGEN UPSTREAM OF OUTFALL (mg/L).............? 8.0
     TOTAL BOD LEVEL IN RIVER UPSTREAM OF OUTFALL (mg/L).....? 1.7

     PRESS ENTER TO CONTINUE.....



     B. EFFLUENT CONDITIONS
     **********************

     EFFLUENT DISCHARGE RATE (m3/s)......................? 0.752
     DISSOLVED OXYGEN IN EFFLUENT (mg/L).................? 0
     TOTAL BOD LEVEL IN EFFLUENT (mg/L)..................? 133.5
     TEMPERATURE OF EFFLUENT (deg C).....................? 20.0
     BOD DECAY RATE COEFFICIENT @ 20 deg (1/day).........? 0.175


     NOTE:

     Mixed temperature D/S of outfall......... 20.00 deg C
     Saturated oxygen level D/S of outfall....  8.45 mg/L
     Mixed oxygen level D/S of outfall........  7.98 mg/L
     Oxygen deficit D/S of outfall............  0.47 mg/L
     Mixed total BOD level D/S of outfall....   2.07 mg/L
     Distance travelled in five days..........   553 km

     PRESS ENTER TO CONTINUE.....
```

```
C. REAERATION CONSTANT
**********************

Churchill's reaeration rate      K20 =  3.128 1/day
Churchill's temp corrected value  K2 =  3.128 1/day
O'Connor's reaeration rate       K20 =  2.318 1/day
O'Connor's temp corrected value   K2 =  2.318 1/day
Owen's reaeration rate           K20 =  2.918 1/day
Owen's temp corrected value       K2 =  2.918 1/day

CHOOSE REAERATION RATE CONSTANT

USEPA suggests Churchill's equation

(1) USE CHURCHILL'S CORRECTED VALUE
(2) USE O'CONNOR'S CORRECTED VALUE
(3) USE OWEN'S CORRECTED VALUE
(4) WILL ENTER OWN VALUE                 MAKE SELECTION.....4

ENTER K2 VALUE (base e, 1/day)..... 1.0

PRESS ENTER TO CONTINUE.....



D. BOD DECAY RATE
*****************

Temp Corrected BOD Decay Rate  K1 =  0.175 1/day

CHOOSE BOD DECAY RATE:

(1) USE CORRECTED VALUE ABOVE
(2) WILL ENTER OWN VALUE                 MAKE SELECTION.....1


NOTE: Reaeration rate is greater than deoxygenation.
River will reaerate until oxygen saturation is reached.
Examine the output carefully.

ENTER DISTANCE TO EXAMINE (km).....400

PRESS ENTER TO CONTINUE.....
```

```
F. PROFILES OF BOD, DEFICIT AND DO
**********************************

LOCATION   BOD   DO DEFICIT    DO
  (km)    (mg/L)   (mg/L)    (mg/L)
**************************************
   0.0      2.07    0.47     7.98
  26.7      1.98    0.45     8.00
  53.3      1.90    0.42     8.03
  80.0      1.82    0.40     8.05
 106.7      1.75    0.38     8.07
 133.3      1.67    0.37     8.09
 160.0      1.60    0.35     8.10
 186.7      1.54    0.33     8.12
 213.3      1.47    0.32     8.13
 240.0      1.41    0.30     8.15
 266.7      1.35    0.29     8.16
 293.3      1.30    0.28     8.17
 320.0      1.25    0.27     8.19
 346.7      1.19    0.25     8.20
 373.3      1.14    0.24     8.21
 400.0      1.10    0.23     8.22

ENTER: 1 FOR ANOTHER RUN OR, 2 TO STOP
```

```
*** DOANAL -- DISSOLVED OXYGEN ANALYSIS -- STANDARD VERSION ***
      *** VERSION 1.1 -- JULY 1985 -- BY JOHN HODGSON ***

     TITLE.....? ATHABASCA RIVER D/S WINDFALL -- FALL

     A. RIVER CONDITIONS
     *******************

     RIVER DISCHARGE (m3/s)...................................? 110
     AVERAGE RIVER VELOCITY (m/s).............................? 0.91
     HYDRAULIC DEPTH (m)......................................? 0.91
     TEMPERATURE IN RIVER U/S OF OUTFALL (degrees C).........? 9.0
     AVERAGE ELEVATION OF REACH (m)...........................? 670

     NOTE: Saturated dissolved oxygen level upstream is 10.69 mg/L
           (corrected for temperature and elevation)

     DISSOLVED OXYGEN UPSTREAM OF OUTFALL (mg/L).............? 10.2
     TOTAL BOD LEVEL IN RIVER UPSTREAM OF OUTFALL (mg/L).....? 1.7

     PRESS ENTER TO CONTINUE.....




     B. EFFLUENT CONDITIONS
     **********************

     EFFLUENT DISCHARGE RATE (m3/s)......................? 0.752
     DISSOLVED OXYGEN IN EFFLUENT (mg/L).................? 0
     TOTAL BOD LEVEL IN EFFLUENT (mg/L)..................? 133.5
     TEMPERATURE OF EFFLUENT (deg C).....................? 20.0
     BOD DECAY RATE COEFFICIENT @ 20 deg (1/day).........? 0.175


     NOTE:

     Mixed temperature D/S of outfall.........   9.07 deg C
     Saturated oxygen level D/S of outfall....  10.68 mg/L
     Mixed oxygen level D/S of outfall........  10.13 mg/L
     Oxygen deficit D/S of outfall............   0.55 mg/L
     Mixed total BOD level D/S of outfall....    2.59 mg/L
     Distance travelled in five days..........    393 km

     PRESS ENTER TO CONTINUE.....
```

```
C. REAERATION CONSTANT
**********************

Churchill's reaeration rate        K20 =  5.360 1/day
Churchill's temp corrected value    K2 =  4.146 1/day
O'Connor's reaeration rate         K20 =  4.262 1/day
O'Connor's temp corrected value     K2 =  2.866 1/day
Owen's reaeration rate             K20 =  6.070 1/day
Owen's temp corrected value         K2 =  4.680 1/day

CHOOSE REAERATION RATE CONSTANT

USEPA suggests Churchill's equation

(1) USE CHURCHILL'S CORRECTED VALUE
(2) USE O'CONNOR'S CORRECTED VALUE
(3) USE OWEN'S CORRECTED VALUE
(4) WILL ENTER OWN VALUE                  MAKE SELECTION.....4

ENTER K2 VALUE (base e, 1/day)..... 1.0

PRESS ENTER TO CONTINUE.....
```

```
D. BOD DECAY RATE
*****************

Temp Corrected BOD Decay Rate  K1 =  0.044 1/day

CHOOSE BOD DECAY RATE:

(1) USE CORRECTED VALUE ABOVE
(2) WILL ENTER OWN VALUE                  MAKE SELECTION.....1


NOTE: Reaeration rate is greater than deoxygenation.
River will reaerate until oxygen saturation is reached.
Examine the output carefully.

ENTER DISTANCE TO EXAMINE (km).....400

PRESS ENTER TO CONTINUE.....
```

```
F. PROFILES OF BOD, DEFICIT AND DO
**********************************

LOCATION   BOD   DO DEFICIT    DO
  (km)    (mg/L)   (mg/L)    (mg/L)
**************************************
   0.0      2.59    0.55    10.13
  26.7      2.56    0.42    10.26
  53.3      2.52    0.33    10.34
  80.0      2.48    0.27    10.41
 106.7      2.44    0.22    10.45
 133.3      2.41    0.19    10.49
 160.0      2.37    0.16    10.51
 186.7      2.34    0.15    10.53
 213.3      2.30    0.13    10.54
 240.0      2.27    0.12    10.55
 266.7      2.24    0.12    10.56
 293.3      2.20    0.11    10.56
 320.0      2.17    0.11    10.57
 346.7      2.14    0.10    10.57
 373.3      2.11    0.10    10.58
 400.0      2.08    0.10    10.58

ENTER: 1 FOR ANOTHER RUN OR, 2 TO STOP
```

```
*** DOANAL -- DISSOLVED OXYGEN ANALYSIS -- STANDARD VERSION ***
     *** VERSION 1.1 -- JULY 1985 -- BY JOHN HODGSON ***

    TITLE.....? ATHABASCA RIVER D/S WINDFALL -- WINTER

    A. RIVER CONDITIONS
    *******************

    RIVER DISCHARGE (m3/s)..................................? 32
    AVERAGE RIVER VELOCITY (m/s)............................? 0.44
    HYDRAULIC DEPTH (m).....................................? 0.56
    TEMPERATURE IN RIVER U/S OF OUTFALL (degrees C).........? 0.5
    AVERAGE ELEVATION OF REACH (m)..........................? 670

    NOTE: Saturated dissolved oxygen level upstream is 13.19 mg/L
          (corrected for temperature and elevation)

    DISSOLVED OXYGEN UPSTREAM OF OUTFALL (mg/L).............? 9.2
    TOTAL BOD LEVEL IN RIVER UPSTREAM OF OUTFALL (mg/L).....? 1.7

    PRESS ENTER TO CONTINUE.....



    B. EFFLUENT CONDITIONS
    **********************

    EFFLUENT DISCHARGE RATE (m3/s)......................? 0.752
    DISSOLVED OXYGEN IN EFFLUENT (mg/L).................? 0.0
    TOTAL BOD LEVEL IN EFFLUENT (mg/L)..................? 133.5
    TEMPERATURE OF EFFLUENT (deg C).....................? 20.0
    BOD DECAY RATE COEFFICIENT @ 20 deg (1/day).........? 0.175


    NOTE:

    Mixed temperature D/S of outfall.........  0.95 deg C
    Saturated oxygen level D/S of outfall.... 13.03 mg/L
    Mixed oxygen level D/S of outfall........  8.99 mg/L
    Oxygen deficit D/S of outfall............  4.05 mg/L
    Mixed total BOD level D/S of outfall....   4.73 mg/L
    Distance travelled in five days..........   190 km

    PRESS ENTER TO CONTINUE.....
```

```
C. REAERATION CONSTANT
**********************

Churchill's reaeration rate      K20 =  5.972 1/day
Churchill's temp corrected value  K2 =  3.815 1/day
O'Connor's reaeration rate       K20 =  6.139 1/day
O'Connor's temp corrected value   K2 =  3.072 1/day
Owen's reaeration rate           K20 =  9.159 1/day
Owen's temp corrected value       K2 =  5.818 1/day

CHOOSE REAERATION RATE CONSTANT

USEPA suggests Owen's equation

(1) USE CHURCHILL'S CORRECTED VALUE
(2) USE O'CONNOR'S CORRECTED VALUE
(3) USE OWEN'S CORRECTED VALUE
(4) WILL ENTER OWN VALUE                 MAKE SELECTION.....4

ENTER K2 VALUE (base e, 1/day)..... 0.0

PRESS ENTER TO CONTINUE.....



D. BOD DECAY RATE
*****************

Temp Corrected BOD Decay Rate  K1 =  0.016 1/day

CHOOSE BOD DECAY RATE:

(1) USE CORRECTED VALUE ABOVE
(2) WILL ENTER OWN VALUE                 MAKE SELECTION.....2

ENTER K1 VALUE (base e, 1/day)..... 0.032


NOTE: Decay rate is greater than reaeration rate.
Oxygen will deplete until either oxygen or BOD is gone.
Examine the output carefully.

ENTER DISTANCE TO EXAMINE (km).....400

PRESS ENTER TO CONTINUE.....
```

```
F. PROFILES OF BOD, DEFICIT AND DO
**********************************

LOCATION   BOD   DO DEFICIT    DO
  (km)    (mg/L)   (mg/L)    (mg/L)
**************************************
   0.0      4.73    4.05     8.99
  26.7      4.62    4.15     8.88
  53.3      4.52    4.25     8.78
  80.0      4.42    4.35     8.68
 106.7      4.32    4.45     8.58
 133.3      4.22    4.55     8.49
 160.0      4.13    4.64     8.39
 186.7      4.04    4.73     8.30
 213.3      3.95    4.82     8.21
 240.0      3.86    4.91     8.12
 266.7      3.78    5.00     8.04
 293.3      3.69    5.08     7.95
 320.0      3.61    5.16     7.87
 346.7      3.53    5.24     7.79
 373.3      3.45    5.32     7.71
 400.0      3.38    5.40     7.64

ENTER: 1 FOR ANOTHER RUN OR, 2 TO STOP
```

APPENDIX B

MIXAPPLN MODEL OUTPUT

```
      PREDICTIONS OF RUNS FOR MANAGEMENT OPTIONS--MIXAPPLN MODEL
      REVISED VERSION BY SAEL JULY 1985

      ATHABASCA RIVER D/S WINDFALL -- OPEN WATER -- COLOUR


  * * RUN NO.:     1

     EFFLUENT FLOW RATE-QEFL(M3/S)..............................  0.752
     U/S RIVER FLOW RATE-QRUP(M3/S).............................  110.000
     WATER TEMPERATURE-TMP(DEG C)..............................20.0
     PH........................................................ 7.0
     CONC. OF EFFLUENT-CEFL(MG/L).............................. 7000.000
     OBJECTIVE CONC.-CS(MG/L).................................. 35.000
     BACKGROUND CONC.-CBKG(MG/L)...............................  5.000
     TEMP CORRECTED BACKGROUND DECAY RATE-RBT(1/DAY)........... 0.00010
     TOTALLY MIXED CONC.(BEFORE DECAY)-CA(MG/L)................ 52.496

DISTANCE              OUTFALL                            PARTIAL CUMULATIVE FLOW-QZ/QT                                         FAR BANK
    X         EZ        0.0        0.1        0.2        0.3        0.4        0.5        0.6        0.7        0.8        0.9        1.0        CAVG

    100.0  0.0565  1443.935      6.076      5.000      5.000      5.000      5.000      5.000      5.000      5.000      5.000      5.000      52 496
    500.0  0.0565   648.511    157.510      7.030      5.002      5.000      5.000      5.000      5.000      5.000      5.000      5 000      52 496
   2000.0  0.0565   326.755    229.497     81.255     17.609      6.015      5.040      5.001      5.000      5.000      5.000      5 000      52.496
   7500.0  0.0565   171.152    155.946    118.180     75.041     40.774     20.080     10.247      6.507      5.357      5.071      5.023      52.496
  30000.0  0.0565    88.085     86.120     80.506     72.019     61.767     50.973     40.773     32.075     25.509     21.450     20 080      52.496
  60000.0  0.0565    64.707     64.107     62.368     59.663     56.261     52.500     48.748     45.372     42.699     40.985     40 395      52 496
 120000.0  0.0565    54.076     54.000     53.779     53.435     53.002     52.521     52.041     51.608     51.264     51.043     50 967      52 496
 210000.0  0.0565    52.587     52.583     52.573     52.557     52.537     52.516     52.494     52.474     52.458     52.448     52 444      52.496

     MAX D/S DISTANCE TO CS (WITH CEFL)-XSCE(M).................    -999.
     NO. OF ITERATIONS-ITRN.....................................       0
     MAX MIXING ZONE LENGTH-XMZ(M).............................. 115177.
     MIXED CONC. (5% CRITERIA)-CMZ(MG/L)........................ 52.522
     DISTANCE TO WATER POLLUTION CONTROL CENTER-XWCP(M)......... 123000.
     SHORE CONC. AT WCPC-CWCP(MG/L)............................. 53.924
     AVERAGE CONC. AT WPCP-CAWP(MG/L)........................... 52.521

            CRITICAL POINT METHOD RESULTS

          LUZ        XL        CL          CEA       XSCEA     ITERATIONS
          0.20     5758.8   120.007      2041.55    14838.84        5
          0.30    12957.0    81.670      2999.86    32356.20        2
          0.40    23034.0    62.502      3919.88    60000.00        1
```

```
      PREDICTIONS OF RUNS FOR MANAGEMENT OPTIONS--MIXAPPLN MODEL
      REVISED VERSION BY SAEL JULY 1985

      ATHABASCA RIVER D/S WINDFALL -- OPEN WATER -- COLOUR


  * * RUN NO.:     2

     EFFLUENT FLOW RATE-QEFL(M3/S)..............................  0.752
     U/S RIVER FLOW RATE-QRUP(M3/S).............................  270.000
     WATER TEMPERATURE-TMP(DEG C)..............................20.0
     PH........................................................ 7.0
     CONC. OF EFFLUENT-CEFL(MG/L).............................. 7000.000
     OBJECTIVE CONC.-CS(MG/L).................................. 35.000
     BACKGROUND CONC.-CBKG(MG/L)...............................  5.000
     TEMP CORRECTED BACKGROUND DECAY RATE-RBT(1/DAY)........... 0.00010
     TOTALLY MIXED CONC.(BEFORE DECAY)-CA(MG/L)................ 24.428

DISTANCE              OUTFALL                            PARTIAL CUMULATIVE FLOW-QZ/QT                                         FAR BANK
    X         EZ        0.0        0.1        0.2        0.3        0.4        0.5        0.6        0.7        0.8        0.9        1 0        CAVG

    100.0  0.1230   495.045      8.336      5 000      5.000      5.000      5.000      5 000      5.000      5.000      5 000      5 000      24 428
    500.0  0.1230   224.155     85.789      9.047      5.028      5.000      5 000      5 000      5 000      5 000      5.000      5 000      24 428
   2000.0  0.1230   114.577     90.383     45.394     16.603      7.024      5.214      5.014      5 001      5.000      5.000      5 000      24 428
   7500.0  0.1230    61.585     57.943     48.364     36.093     24.517     15.724     10.159      7.173      5 805      5 276      5 146      24 428
  30000.0  0.1230    33.365     32.913     31.609     29.594     27.084     24.338     21.633     19 225     17.337     16.136     15 724      24 428
  60000.0  0.1230    26.442     26.344     26.060     25.617     25.059     24.441     23.822     23 265     22 822     22 538     22 440      24 428
 120000.0  0.1230    24.542     24.537     24.523     24.500     24 471     24 439     24 408     24 379     24 356     24 342     24.336      24 428
 210000.0  0.1230    24.439     24.439     24.438     24.438     24 438     24 437     24 437     24.437     24 436     24 436     24 436      24 428

     MAX D/S DISTANCE TO CS (WITH CEFL)-XSCE(M).................   24830.
     NO  OF ITERATIONS-ITRN.....................................       6
     MAX MIXING ZONE LENGTH-XMZ(M)..............................   79835
     MIXED CONC. (5% CRITERIA)-CMZ(MG/L)........................ 24.440
     DISTANCE TO WATER POLLUTION CONTROL CENTER-XWCP(M)......... 123000.
     SHORE CONC. AT WCPC-CWCP(MG/L)............................. 24 528
     AVERAGE CONC. AT WPCP-CAWP(MG/L)........................... 24.439

            CRITICAL POINT METHOD RESULTS

          LUZ        XL        CL          CEA       XSCEA     ITERATIONS
          0.20     3991.7    52.044      4707 55    10218.69        4
          0.30     8981.3    36.363      6737 71    22856 43        6
          0.40    15966.6    28.522      8589.95    40875.39        4
```

```
          SUMMARY OF RUNS FOR MANAGEMENT OPTIONS

          ATHABASCA RIVER D/S WINDFALL -- OPEN WATER -- COLOUR


   RUN#   QEFL      QRUP     TEMP     PH      CAWP      XSCE     LUZ      CEA       XSCEA


     1.   0.752   110.00     20.0     7.0    52.521    -999.0   0.20   2041.55    14838 8
                                                                0.30   2999.86    32356.2
                                                                0 40   3919.88    60000.0


     2.   0.752   270 00     20.0     7 0    24.439   24830.3   0 20   4707 55    10218.7
                                                                0 30   6737.71    22856 4
                                                                0.40   8589.95    40875.4
```

INDUSTRIAL PROJECTS

Clean Water Act

Procedures and methods for evaluating water quality changes in receiving streams

Alberta

ENVIRONMENT

Standards and Approvals Division
Water Quality Branch

INTRODUCTION

The demands on the surface water resources in Alberta are increasing. To protect the needs of the users (i.e. human, aquatic life, industrial, agricultural, and recreational), water quality must be adequately maintained. By prescribing methods of assessing water quality changes, Alberta Environment hopes to guide industrial proponents in completing applications under the Clean Water Act more effectively.

The proposed discharge of an industrial effluent to a water course alters the water quality of the stream and may result in conflict among stream users. Anticipated water quality impacts of certain parameters and their zone of influence within a stream is crucial in identifying potential resource use conflicts and developing appropriate cost effective mitigation strategies.

The procedures and methods to be used for assessing water quality changes in a receiving stream are presented according to Level I, II and III analyses as shown in the schematic.

Assessing water quality changes could be conducted in either a full environmental impact assessment or as an addendum in support of an application under the Clean Water Act. This handout outlines the procedures and methods associated with the Clean Water Act application.

More detailed information on the procedures and methods is provided in the report Procedures And Methods For Evaluating Water Quality Changes In Receiving Streams and can be obtained from the Water Quality Branch, Standards and Approvals Division, Alberta Environment.

LEVEL I ANALYSIS

Level I analysis provides an initial evaluation of the effects of the effluent on the receiving stream. Parameters that are out of compliance with the water quality guidelines and which require further analysis or upgraded treatment are identified. Level I analysis comprises the following:

Effluent Characteristics

At the outset, a proponent must determine the effluent parameters, their concentrations, and loadings to the stream. Effluent guidelines outlining the restrictions associated with the type of industrial effluent, can be obtained from the Water Quality Branch, Standards and Approvals Division, Alberta Environment.

Receiving Stream Characteristics

A proponent must evaluate the sensitivity of a receiving stream in terms of water quality and water uses. The stream uses can be categorized as domestic, fisheries, agriculture, industrial, wildlife, or recreation. The appropriate ambient water quality guidelines associated with a specific water use can be obtained through consultation with the Water Quality Branch, Standards and Approvals Division. Background water quality data for the stream must also be obtained.

The hydrologic and hydraulic characteristics of the receiving stream must be determined. These comprise seasonal flow variations, the frequency of low flows at the effluent discharge point and at various locations downstream. Hydraulic considerations include determining representative cross-sectional information.

Dilution Analysis

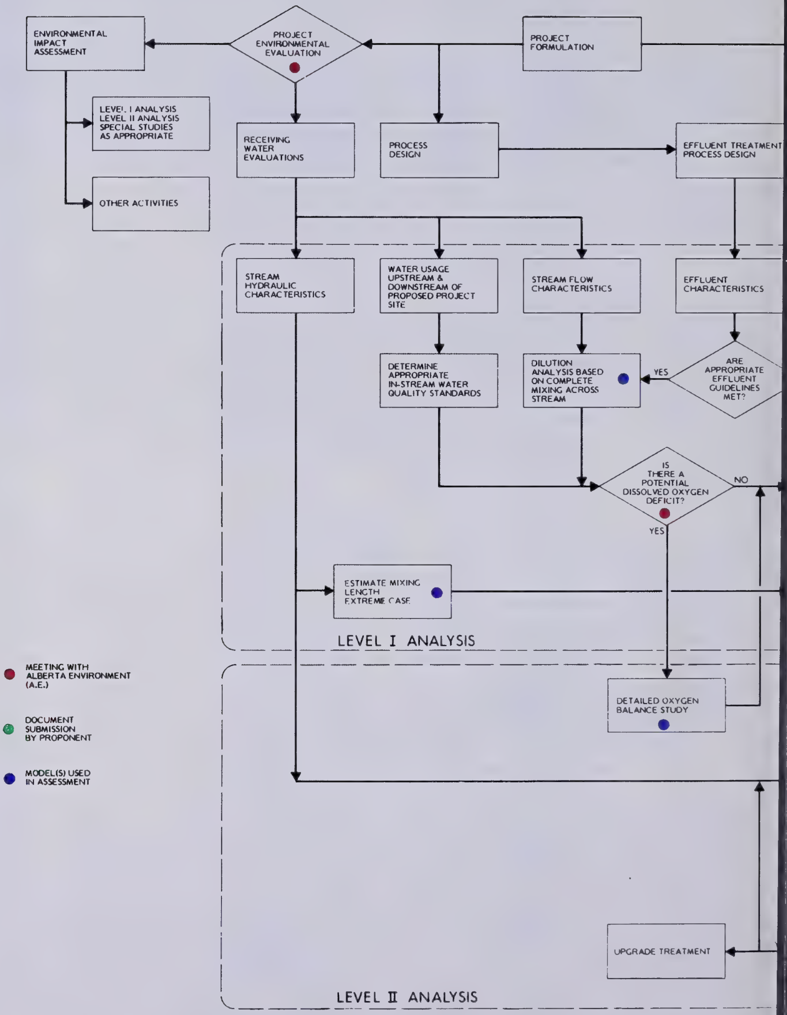
Dilution analysis must be conducted to determine the compliance and/or non-compliance of each of the effluent parameters with the water quality objectives, assuming complete mixing of the effluent in the stream. From this analysis, the need for further treatment of the effluent or a more rigorous analysis (Levels II or III) is determined.

Mixing Zone Evaluation

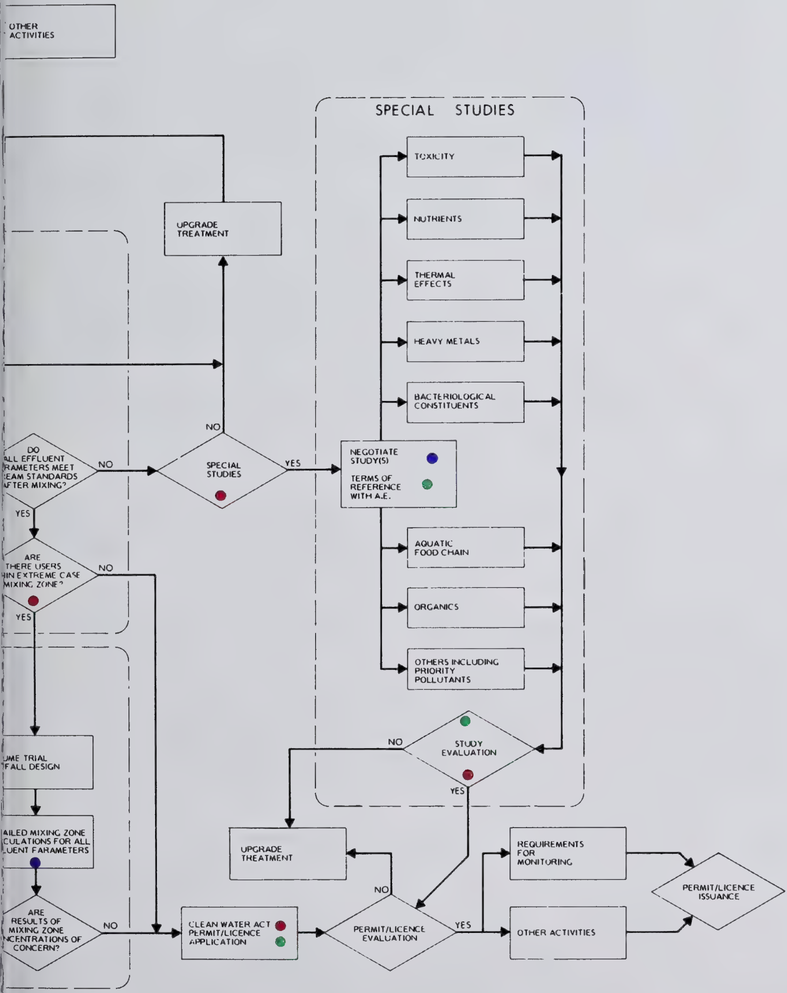
The length of the mixing zone must be quantified to determine its significance as an area of possible non-compliance. The extent of the mixing zone can be delineated by using a nomograph which is based on a simplified mathematical model of two-dimensional dispersion.

Dissolved Oxygen Evaluation

The discharge of an effluent may result in a reduction of dissolved oxygen in a stream. A nomograph which is based on the Streeter-Phelps dissolved oxygen sag equation can be used to determine the dissolved oxygen deficit for various Biochemical Oxygen Demand loading levels and stream conditions. This evaluation indicates whether further analysis is required in Level II.


ENVIRONMENTAL IMPACT ASSESSMENT
PROJECT ENVIRONMENTAL EVALUATION
PROJECT FORMULATION
LEVEL I ANALYSIS LEVEL II ANALYSIS SPECIAL STUDIES AS APPROPRIATE
OTHER ACTIVITIES
RECEIVING WATER EVALUATIONS
PROCESS DESIGN
EFFLUENT TREATMENT PROCESS DESIGN
STREAM HYDRAULIC CHARACTERISTICS
WATER USAGE UPSTREAM & DOWNSTREAM OF PROPOSED PROJECT SITE
STREAM FLOW CHARACTERISTICS
EFFLUENT CHARACTERISTICS
DETERMINE APPROPRIATE IN-STREAM WATER QUALITY STANDARDS
DILUTION ANALYSIS BASED ON COMPLETE MIXING ACROSS STREAM
YES
ARE APPROPRIATE EFFLUENT GUIDELINES MET?
IS THERE A POTENTIAL DISSOLVED OXYGEN DEFICIT?
NO
YES
ESTIMATE MIXING LENGTH EXTREME CASE
LEVEL I ANALYSIS
DETAILED OXYGEN BALANCE STUDY
UPGRADE TREATMENT
LEVEL II ANALYSIS
● MEETING WITH ALBERTA ENVIRONMENT (A.E.)
● DOCUMENT SUBMISSION BY PROPONENT
● MODEL(S) USED IN ASSESSMENT

Schematic showing procedures for evaluating a singl
licence to operate under the Clean Water Act.



oint industrial discharge associated with the permit to construct and

LEVEL II MIXING ZONE ANALYSIS

The need and extent of the Level II analysis are determined by the findings from Level I analysis. If the effluent parameters complied with the water quality guidelines after complete mixing and within the mixing zone, and if the dissolved oxygen levels were adequate for the protection of aquatic life, the proponent can proceed with a permit/licence application. However, if some parameters exceeded the allowable limits within the mixing zone, Level II analysis is required.

Therefore, the major objectives in Level II analysis are delineating the size of the zone of non-compliance under various stream conditions and determining the allowable effluent load in order to meet the mixing zone criteria.

Mixing Model

A detailed mixing zone model, such as MIXAPPLN, should be used to meet the objectives in Level II. For each parameter, the model determines the spatial distribution of the concentrations in the mixing zone. The model should also simulate decay characteristics. The potential uses of such a model are as follows:

- predicting lateral concentration profiles of a parameter as a function of the partial cumulative discharge at all river transects,
- predicting the behaviour of conservative and non-conservative parameters (non-conservative parameters can be examined as a function of temperature and, in the special case of ammonia, the decay rate of ionized and unionized ammonia can be determined as a function of pH),

- effects of bank outfalls and instream diffusers can be assessed in terms of downstream concentration profiles,

- predicting the distance along the stream bank from the outfall to the location where the concentration is less than a specified criterion concentration,

- predicting the distance to the point of complete mixing,

- predicting concentrations along the bank at a specified distance downstream (usually associated with a constraining water use),

- predicting allowable effluent concentrations for a specified width of the limited use zone within a stream, and

- estimating the distance along the stream bank from the outfall to the criterion concentration for various widths of the limited use zone.

If the results of the modelling reveal water quality concerns (i.e., predicted deviation from ambient water quality levels beyond those levels prescribed for the specific water use category), then upgrading the treatment of the effluent would be required. However, if the results are of no concern, the proponent may proceed with the permit/licence application.

LEVEL III ANALYSIS

Level III analyses are special studies that may be required after the Level I analysis to further define the impacts of water quality parameters. The nature and scope of such studies should be initiated through negotiations with the Water Quality Branch, Standards and Approvals Division. Most of the special studies identified on the schematic can be evaluated through the use of models.

For further information contact:

Alberta Environment
Standards and Approvals Division
Water Quality Branch at

427-5888